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mHealth App to improve medication adherence among older adult stroke survivors: Development and usability study

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Abstract

Background: Effective medication adherence is vital for older adult stroke survivors, yet 20–33% cease treatment within a year post-discharge, increasing risks of recurrent strokes and mortality. A mobile health (mHealth) app could be a novel tool to improve medication adherence among stroke survivors because of its potential to increase patient empowerment. A few stroke-related apps provide information and support to stroke survivors. However, none have focused on medication adherence and documented their development and evaluation process, particularly those focused on this older population.

Objective: This study aims to design and develop a smartphone app called OASapp to improve medication adherence among older adult stroke survivors and evaluate its usability.

Methods: OASapp was developed in a three-phase development process. Phase 1 is the exploration phase (including a cross-sectional survey, a systematic review, a search for stroke apps on the app stores of Apple App Store and Google Play Store, and a nominal group technique). In phase 2, a prototype was designed based on the Health Belief Model and Technology Acceptance Model. In phase 3, Alpha and Beta testing was conducted to validate the app.

Results: Twenty-five features for inclusion in the app were collected in round one, and 14 features remained and were ranked by the participants during nominal group technique. OASapp included five core components (medication management, risk factor management, health information, communication, and stroke map). Users of OASapp were satisfied based on reports from Alpha and Beta testing. The mean Usability Metric for User Experience (UMUX) score was 71.4 points (SD 14.6 points).

Conclusion: OASapp was successfully developed using comprehensive, robust, and theory-based methods and was found to be highly accepted by users. Further research is needed to establish the clinical efficacy of the app so that it can be utilized to improve clinically relevant outcomes.

Keywords

mHealth app, mHealth development process, medication adherence, eHealth, mHealth, mobile apps, usability, older adult stroke survivors

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Introduction

Stroke remains the second leading cause of death and a major contributor to disability worldwide. The estimated cases of stroke would continuously increase due to the sub-optimal management of stroke-related diseases (e.g. hypertension, atrial fibrillation, hyperlipidemia, and diabetes).[1] Medication adherence is considered a substantial and crucial attempt to prevent stroke.[2] However, there is a large volume of published studies describing medication adherence among stroke survivors is problematic.[3,4] Adhering to medication can be challenging for stroke patients due to concerns about long-term use, memory challenges, financial constraints, side effects, and regimen complexity.[5–7] A consensus among social scientists indicates that medication non-adherence is associated with increased risk of stroke events and all-cause mortality.[8,9] As such, measures should be implemented to enhance medication adherence among this population. Brown et al.[10] demonstrated that improving medication adherence may have greater effect on the population's health than any improvements in new therapies.

Several attempts have been implemented to improve medication adherence among stroke survivors. However, Wessol et al.[11] conducted randomized controlled trial interventions to increase medication adherence in adult stroke survivors and concluded that despite some isolated success, most interventions had shown limited effectiveness. The worldwide development and adoption of affordable smartphones in the last several years has brought enormous advantages toward influencing the behavior of patients. The advancement of apps is unavoidable and has the potential to facilitate interventions because they can improve engagement with established strategies for prevention and treatment of diseases through individualized dosing reminders, personalized goal setting, and gamification.[12] Zeng et al.[13] indicated that the development and testing of mHealth intervention programs for stroke survivors is still at an early stage, and evidence of their effects are limited. Furthermore, apps are increasingly used to assist older people in staying connected to friends and family, remaining active, and self-managing chronic illnesses.[14,15] Many medication adherence apps are currently available given the accessibility and widespread use of mobile phones[16]; however, these apps are not specific to diseases, such as stroke. Piran et al.[17] pointed out that most apps exist to specifically support stroke survivors/caregivers and primarily focus on language and communication difficulties instead of medication adherence. Our recent review found that a feature related to medication is not one of the primary features of stroke-related apps.[18]

A few stroke-related apps provide information and support to stroke survivors, but none have comprehensively documented their development process and usability, which will allow future researchers to develop similar mHealth apps and may be especially useful for the more innovative aspects of mHealth (e.g. design principles, technical features, and the presentation of information). Moreover, a theory-based app could stress and sustain health promotion behavior change; otherwise, the app's effectiveness could be limited.[19,20] The Health Belief Model (HBM) and Technology Acceptance Model (TAM) provide a well-defined framework for the development of apps.[21,22] Accordingly, this study reports on the design and development of a mHealth app, namely, OAS, based on HBM and TAM to improve medication adherence among older adult stroke survivors.

Methods

Overview

The app was developed in three phases (Figure 1). The researcher conducted the development process with a technology team and an expert advisory panel (EAP). The EAP consisted of three stroke experts, a nurse, a doctor, and a pharmacist, each with abundant experience in clinic care targeting stroke survivors. The experts were regarded as project consultants, and they provided consultation or feedback throughout the prototype design and development process. The technology team was responsible for the prototype's design and programming and consisted of four people (e.g. a technology director, an app developer, a user experience and graphic designer, and a database engineer).

Phase 1 involves three steps. In step 1, a cross-sectional study was conducted to determine the prevalence of medication non-adherence and its associated factors among older adult stroke survivors in China. This step is important in creating an appropriate strategy to improve medication adherence. In step 2, a systematic review of stroke apps

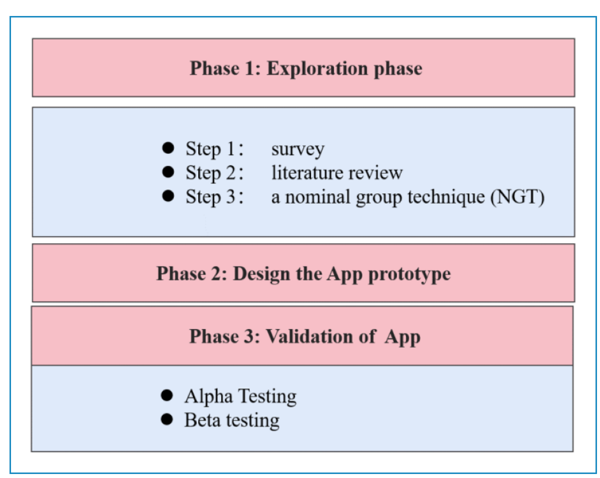

Figure 1. App development process.

in the literature, Apple App Store, and Google Play Store was conducted to gather ideas for the development and content of the app. In step 3, a nominal group technique (NGT) was applied to develop the framework and content of the app. Phase 2 included the design of the app and development of its overall structure. In phase 3, Alpha and Beta testing was conducted to validate the relevance, appropriateness, practicality, and clear aspects of the mobile app.

Phase 1: exploration phase

Step 1: survey of medication non-adherence and associated factors among older adult stroke survivors in China. A cross-sectional study on 402 older adult stroke survivors was conducted from June 2022 to August 2022 by using the following questionnaires: the General Medication Adherence Scale,[23] Beliefs about Medicines Questionnaire,[24] and Health Literacy Scale for Stroke Patients.[25] The details of the methodology have been described in a previously published study.[3] The points generated from the survey regarding app development were as follows: the app should provide information on the necessity of treatments as well as the known side effects of prescribed drugs and help participants to share their concerns; older adult stroke survivors are more adherence to medications if it meets their broader health needs medical conditions (e.g. hypertension, history of cardiac-related comorbidities, diabetes, etc.); the app should utilize a reminder function to facilitate adherence to medications; and additional information on hypertension and diabetes would be necessary.

Step 2: systematic review of stroke apps in the literature, Apple App Store and Google Play Store

Overview. We conducted two reviews, namely, a literature review and research in commercial application stores. The study design for review of commercial apps has been reported elsewhere.[18] The details of the literature can be found in our previously published paper.[26] Some important conclusions can be obtained from the literature review: an increasing number of apps targeting stroke survivors are released and mostly geared toward young and middle-aged patients. Developers must address the needs of older age groups and offer enhanced accessibility features. When developing the app, enhanced accessibility features should be offered to increase to older adults groups. For example, the app could launch a care mode, which has large and clear words, vivid colors, good recognition, and large buttons for ease of use.

Step 3: NGT. NGT was conducted to explore three elements:

1. Identify the main issue of medication compliance in elderly diagnosed with stroke,
2. Present the literature review and available apps in the play store, and
3. Identify and prioritize a list of key app features suitable for older adult stroke survivors.

NGT involves a highly structured face-to-face meeting that provides an orderly procedure for obtaining relevant and reliable qualitative information from target groups that are related to the problem area.[27] This technique has been applied in numerous studies to produce ideas and identify solutions within groups and generate recommendations for best practices.[28,29] NGT comprises four key stages: silent generation, round robin, clarification, and voting (ranking or rating).[30] The facilitators presented the content and features of the proposed apps and the techniques and elements suitable for older adult stroke survivors were used for discussion.

Two weeks before the session, the researcher selected and invited the participants for a group session. The researcher briefly discussed the topic and the expected outcome of the session.

Nine participants were included in the discussion group:

1. One neurologist
2. One nursing specialist
3. One education specialist
4. Two pharmacy specialists
5. One public health physician
6. Three representatives from intended users (all of them are older adult stroke survivors above 60 years old).

Two moderators from the research team conducted the session. NGT consisted of six phases (e.g. introduction to the purpose and procedure of the meeting, silent generation of ideas, sharing ideas, discussion of ideas, voting and ranking, and conclusion) which was adopted from the studies of Potter et al.[31] and McMillan et al.[32]:

To be specific, facilitators conducted a literature review on the features of a mobile application (e.g. emergency information collection, risk assessment, reminders, educational information, self-monitoring of blood pressure/lipids/glucose, rehabilitation guidance, communication with healthcare providers and others, and psychological support) expected by users from published research; they shared the findings to the participants and asked them to rank the answers accordingly. The flow of the whole discussion in NGT is shown in Figure 2.

Phase 2: design of app prototype

Inspired by the conception of storyboard in the movie industry,[32] we intended to generate a storyboard to map out and organize ideas based on the findings from the app store review, literature search, cross-sectional study, and NGT in the exploration phase before actually developing the app. The storyboard is the blueprint for the app and

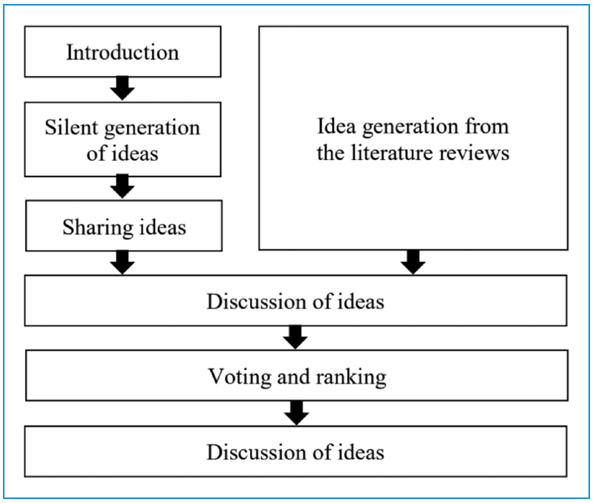

Figure 2. Flow of nominal group technique (adopted from the studies of McMillan et al.[30] and Potter et al.[31]).

describes all the elements that would appear on a single screen. Figure 3 shows the storyboard of the app.

The development of the app prototype can be defined as translating the storyboard into a whole app design. Two project researchers underwent two mobile application development workshops to develop the prototype. The development was based on a framework of guiding interface design for older adults adopted from the study of Liu & Joines[33] as well as guidelines for developing apps for elderly people adopted from the work of Phiriyapokanon.[34] Furthermore, the app was developed based on HBM and TAM (Figure 4). During the prototype development, the researchers considered all inputs from the NGT session. The prototype was developed on the Android platform.

Phase 3: validation of app

Alpha and Beta testing was conducted to validate the relevance, appropriateness, practicality, and clear aspects of the mobile app.

Alpha testing. Alpha testing is known as simulated operational testing on apps that have been developed to identify and solve problems that have arisen. Alpha testing was conducted by involving content experts and an app expert. A stroke specialist and a senior lecturer, who has PhD qualification and is an expert in medication adherence, were involved as content experts in the Alpha testing. The content experts were requested to evaluate the app by filling out an evaluation form (Appendix 1), which was adapted from a previous study.[35] An app expert, whose research interests are usability assessment and product design, was also involved in the Alpha testing. He was responsible for evaluating the usability of the app. After evaluating the app, the app expert was asked to fill out the heuristic evaluation form (Appendix 2) adapted from a previous work.[36]

The experts assessed the comprehensibility, clarity, and technical errors encountered when using the app. Feedback from the content and app experts involved was recorded to improve the quality of the app. Based on the Alpha testing results, the researcher carried out modifications to improve the quality of the app.

Beta testing. After all amendments based on the comments of the experts involved, Beta testing was carried out on the target group, namely, older adults stroke survivors. Beta testing aims to determine (in conjunction with data from Alpha testing) whether the developed prototype meets users' needs in ways that would lead to sustained adoption.[37] According to Mohd & Shahbodin,[38] Beta test is carried out to serve as a trial before conducting a real test. Beta testing determines the usability of the prototype. It is formal process used to understand the usefulness and usability of an application that has been developed.[39] Usefulness is related to how useful the developed application is. Usability refers to the technical operation of the application, which includes two aspects, namely, interface and interaction. Through this test, the researcher determined the effectiveness of the improvements after the Alpha testing. The researcher was also able to identify any weakness or problem about the use of the developed software from the perspective of the target user group.

From the viewpoint of Allesi and Trollip,[39] there are seven steps that must be executed in Beta testing, namely:

(i) Select the participant – in our study, older adults stroke survivors were selected for Beta testing. We enrolled patients from the neurology department of three tertiary hospitals in Chenzhou City of Hunan Province, China (Affiliated Hospital of Xiangnan University, Chenzhou No. 1 People's Hospital, and Chenzhou Third People's Hospital) through purposeful sampling to obtain a maximum variation sample of key stakeholders. The inclusion criteria were as follows: age of 60 years or older; history of stroke; modified Rankin score of three or less; taken at least one medication in the previous month, such as (but not limited to) antiplatelets, statins, and anti-hypertensives to control risk factors for strokes; last stroke episode that occurred more than a month; and ability to read Chinese and communicate in Mandarin Chinese or the local Chenzhou dialect. Patients who had the following were excluded: psychiatric illness or deafness, aphasia, or other language barriers; and cognitive impairment (Mini-Mental State Examination score ≤17 [for illiterate] or ≤20 [individuals with 1–6 years of education] or ≤24 [individuals with 7 or more years of education]). The information sheet and

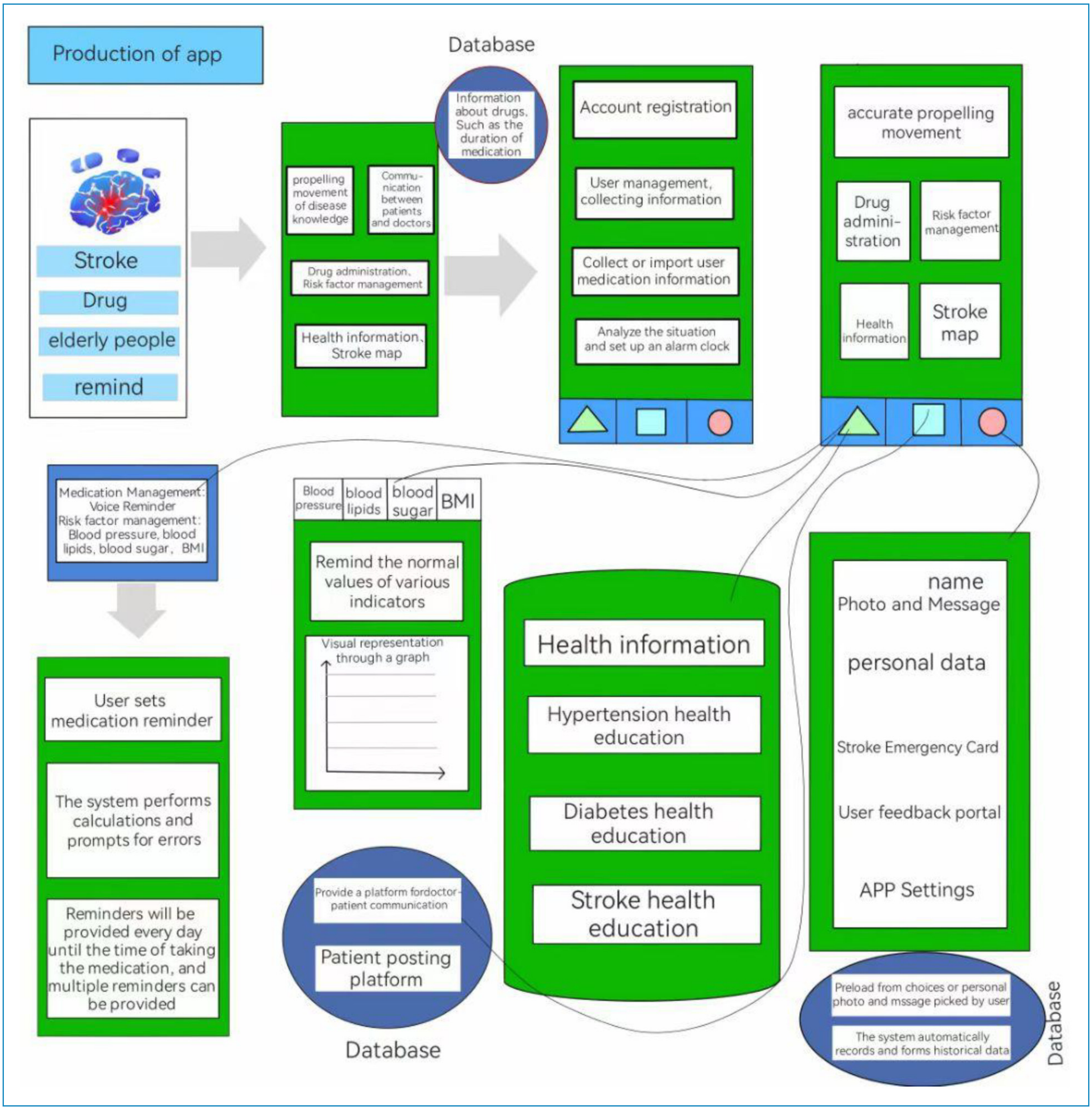

Figure 3. Storyboard of the app.

consent form were given to the patients who indicated willingness to participate.

(ii) Explain the procedure and the purpose – the researcher explained the procedure and purpose of the Beta test to the participants.

(iii) Determine prior knowledge – the researcher determined how much knowledge the patient has about stroke.

(iv) Observe them throughout the whole process – the researcher observed the participants and recorded patterns that emerged from their interactions with the prototype through the program.

(v) Interview them afterward – after the participants interacted with the app prototype, the researcher interviewed them to provide feedback on its usability and content.

(vi) Assess their learning – after the participants interacted with the app prototype, the researcher evaluated how much of the learning process they had.

(vii) Revise the program – the researcher created a plan that covers information about revisions conducted, time needed, and deadline for each revision.

Concepts	Concept Definition	Content generated
Perceived susceptibility	Beliefs about the likelihood of getting a disease or condition	• Description of stroke risk factors
Perceived severity	Beliefs about the seriousness of contracting a disease or condition, including consequences	• Description of the stroke impact
Perceived benefits	Beliefs about the positive aspects of adopting a health behavior (e. g. efficacy of the behavior for reducing risk or serious consequences).	• Description of the benefits derived from taking medication to prevent stroke occurrence
Perceived barriers	Beliefs about obstacles to performing a behavior, and the negative aspects (both tangible and psychological costs) of adopting a health behavior	• Description of the medication required to carry out the proposed preventive activities
Cues to action	Internal or external factors that could trigger the health behavior	• Motivation techniques for adherence to the proposed program (use appropriate reminder)
Self-efficacy	Beliefs that one can perform the recommended health behavior(confidence)	• Give verbal reinforcement.

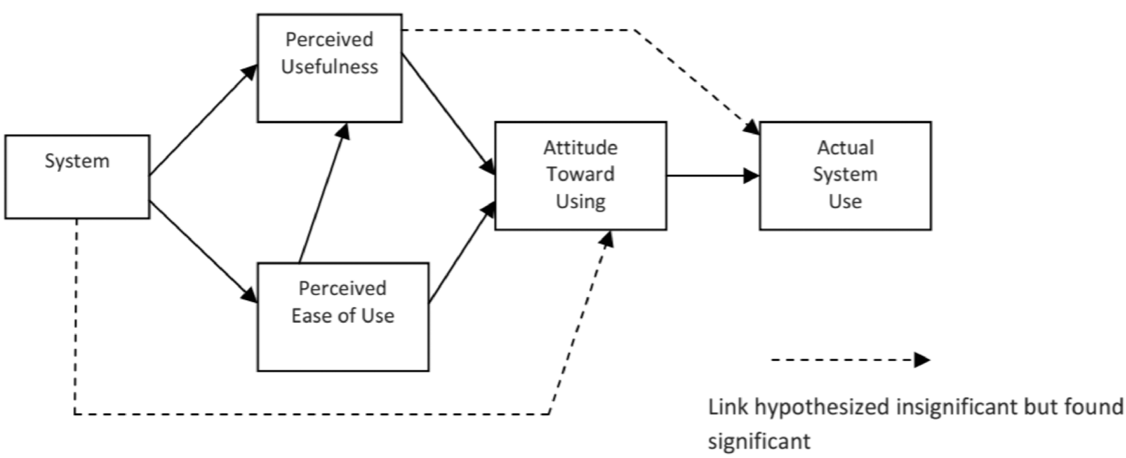

Figure 4. Relationship between the constitutive definitions of HBM and the contents generated in the conceptual modeling of the application (top) and TAM (bottom).

Beta testing was divided into two levels, namely, (1) one-to-one evaluation and (2) small group evaluation.

One-to-one evaluation. Three older adults stroke survivors were involved in the evaluation. The participants were given iPads with a pre-loaded app prototype. The researcher kept the provision of guidance on how to use the app to a minimum to allow the participants to explore the prototype freely and ensure the identification of any potentially unclear features or instructions in the prototype. The participants were with the researcher individually and asked to explore the app under the supervision of the researcher. The researcher observed the participants without interrupting them and recorded patterns that emerged from their reaction towards the app. The participants were then asked to provide detailed feedback on the app, particularly on its content and operation.

Small group evaluation. The researchers helped the patients to download the app, discussed the purpose of the study, and conducted a brief demonstration of the features of the app (e.g. logging into the app on a mobile device, setting medication lists and reminding, using the stroke map, making a BP/ blood glucose entry, viewing a BP graph and sharing it with friends by WeChat, sharing

Table 1. Number of participants who chose specific features.

Feature	Number of votes	Top 5 highest priority
Medication reminders	9 (100%)	1
A drug–drug interaction check	2 (22.2%)	
Risk assessment	5 (55.6%)	
Record medical history	2 (22.2%)	
Pharmacy information	8 (88.9%)	2
Disease information	8 (88.9%)	2
Export information from app	3 (33.3%)	
Hospital information	4 (44.4%)	
Track blood pressure/lipids/glucose	8 (88.9%)	2
Versatility of medication information input and display	4 (44.4%)	
Communication	7 (77.8%)	3
Work with wearables	2 (22.2%)	
Important contacts	3 (33.3%)	
Symptom management	5 (55.6%)	

experience with others, and reviewing the entered health information). The participants were asked to complete pre-specified tasks with the mobile app independently to ensure that they could use all areas/functions of the app. They were then provided with the details of using the app and were asked to test the app for 7 days.

All the participants were given the opportunity to explore the developed app freely, and they were asked to evaluate the app in terms of usability by filling out the form called the Chinese version of the Usability Metric for User Experience (UMUX) adapted from the study of Wang et al.[40] UMUX is a standard usability questionnaire designed to measure perceived usability consistent with the System Usability Scale (SUS) but using only four items (rather than 10 items).[41] The questionnaire is compact enough to serve as a usability module in a broader user experience metric.[41] A reliability analysis of the merged data set resulted in a Cronbach's alpha value of 0.83 for UMUX.[42] Lewis et al.[43] indicated that UMUX provides an alternative metric for perceived usability for situations where reducing the number of items is critical while obtaining accurate usability assessment. The items vary in tone; odd-numbered items have a positive tone, and even-numbered items have a negative tone.[44] UMUX adopts a seven-point Likert scale (1 = Strongly Disagree to 7 = Strongly Agree). It is scored as [score-1] for items one and three and [7-score] for items two and four. The scores for each item are summed, divided by 24, and multiplied by 100.[45] The reliability of the Chinese UMUX is 0.824, and the construct validity KMO of UMUX is 0.787.[40] The correlation between UMUX and SUS is r (173) = 0.829 ($p < 0.01$).[40]

Results

NGT

The NGT results present the various features of the app that were ranked according to their importance. In total, 25 features were collected for inclusion in the app in round one. After selecting, prioritizing, and discussing these features in rounds two and three, 14 features remained and were ranked by the participants. The results of the voting cards were reviewed to determine the features that received the most votes and the ranking of the votes. Of the 14 features identified by the participants, medication reminder was the top feature voted as essential for inclusion in the app. It was followed by track BP/lipids/glucose, disease information, pharmacy information, and communication (Table 1). Furthermore, the NGT findings were used to build a

Table 2. Framework of the app.

No.	Items	Description
1.	Name of the app	OASapp, the abbreviation of older adult stroke application
2.	Objective	To improve medication adherence among older adults stroke survivors
3.	Platform for publishing the app	Android platform
4.	Main functions	Section "Medication management"
		This section has a medication list with reminders to take appropriate doses. It can generate adherence reports and allow a patient to visualize their adherence. The medication lists include indications to ensure that patients are educated. Patients could involve family members or healthcare providers by sharing their medication lists via WeChat.
		Section "Risk factor management"
		This section allows for the self-reporting and storage of BP, capillary glycemia level, blood lipid profile, and BMI readings, producing feedback in the form of graphs and numerical data logs. An export function allows users to share these data via WeChat.
		Section "Health information"
		This section lists patients' knowledge of stroke, such as its definition, signs, and symptoms. It is presented in short videos and textual graphic presentations to improve the effectiveness of information dissemination. Voice Broadcast is applied.
		Section "Communication"
		This section allows patients to chat with health care professionals (HCPs) and other patients. Patients can also browse a list of frequently asked questions.
		Section "Stroke map"
		This section helps patients to identify stroke signs and symptoms with the so-called "Stroke 1-2-0" interface, where 1 represents "First, look for an uneven face," 2 refers to "Second, examine for arm weakness," and 0 refers to "Zero (absence of) clear speech." If a stroke sign is suspected or identified through the three-step procedure, the patient can link the quick recognition to the immediate activation of emergency medical services (EMS) by dialing 1-2-0 to reduce stroke prehospital delay. In addition, nearby hospitals are provided in map and list views, incorporating proximity to the user's location by using the Global Positioning System.
5.	Other ancillary functions	Patients can store their health data in the app (e.g. blood test results, imaging examinations).
		This section allows users to store the emergency contact numbers of family and provides emergency access to them through the app. Patients can access their favorite health information from the "Favorites" screen.

framework of the app (Table 2). The prototype version of the app is registered for national copyright from the China Government (Appendix 3).

Prototype features

OASapp is composed of five components (Figure 5):

- Medication management component
- Risk factor management component
- Health information component
- Communication component
- Stroke map component

Figure 5 shows a screenshot of the app.

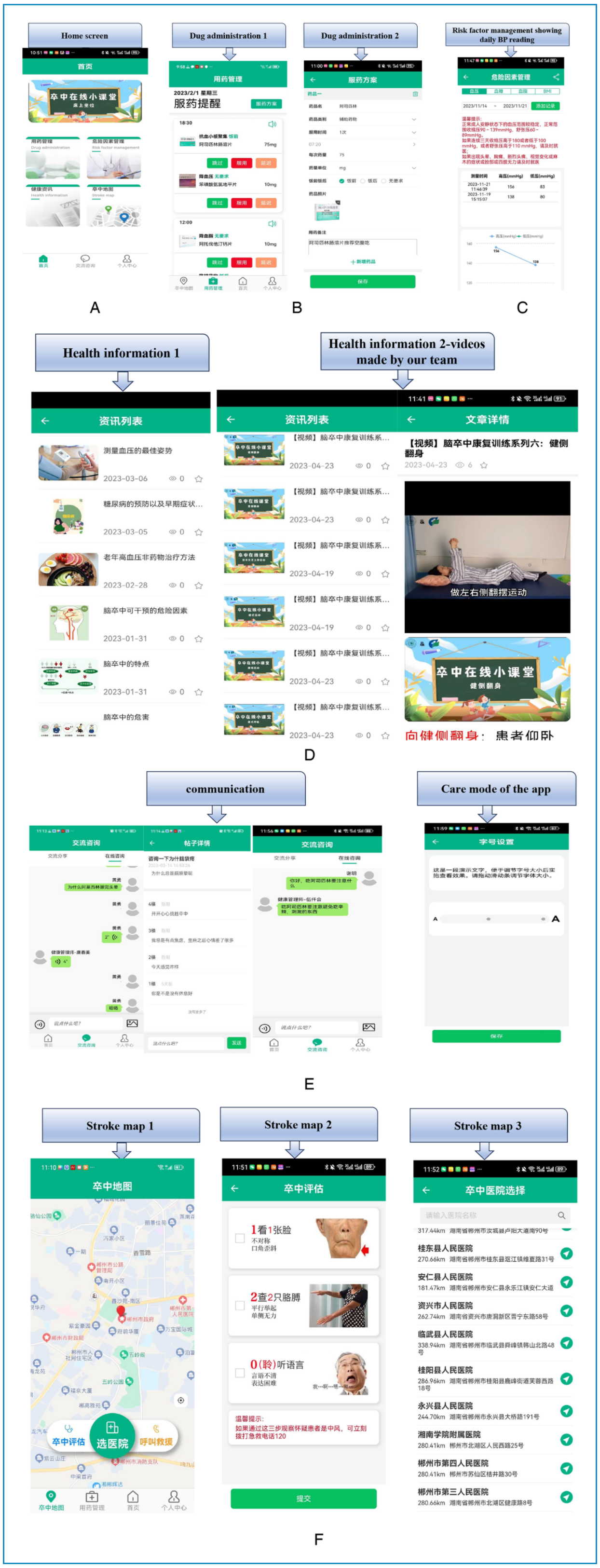

Figure 5. Screenshots of OASapp, including its (A) home page, (B) medication management component, (C) risk factor management component, (D) health information component, (E) communication component, and (F) stroke map component.

Each component is described in detail below.

The medication management component encourages patients to upload their medication schedule (medication name, medication appearance, dosage, unit, and frequency). Patients can receive customized reminders to take their tablets. The medication lists include indications, so patients are educated and make associations with each medication. Participants can add a picture to provide visual clues (e.g. to ensure correct medication is taken). Medication adherence reports can be generated and shared with a healthcare provider or family member by WeChat.

The risk factor management component allows users to input BP, capillary glycemia level, blood lipid profile, and BMI measurements; and view numerical logs as well as 1-week graphs of BP, capillary glycemia level, blood lipid profile, and BMI data. These data can be shared with a medical team or family member by WeChat; as such, the user has easy access to the stored information for future acute or chronic care visits to healthcare providers. If a participant records a BP with systolic reading greater than 180 mmHg or less than 100 mmHg or a diastolic reading of greater than 110 mmHg, then the user will be guided by automated notifications within the app at the time of the elevated reading regarding what to do next. Figure 6 shows an example of a push notification in the app.

The health information component provides users with knowledge on stroke. Topics include the definition, epidemiology, harmful effects, and risk factors of stroke as well as how to identify it. Topics specific to hypertension and diabetes are also provided. All topics were created based on literature review, multidisciplinary expert group meeting, and user needs analysis. All health knowledge were broadcasted by voice.

The communication component provides a platform for active collaboration between healthcare professionals and patients. Users can consult health care professionals about stroke-related questions and share their feelings with other patients.

The stroke map component helps educate users on the key symptoms to look out for and allows them to directly dial 120 (Emergency Medical Services contact all over China). The component adopts a stroke screening tool based on the "Stroke 1-2-0" program, which was developed by adapting Face, Arm, Speech, and Time (FAST) and is regarded as a rapid response program for stroke in China. Stroke 1-2-0 is transformed into three stroke recognition actions, where 1 represents "First, look for an uneven face," 2 represents "Second, examine for arm weakness," and 0 represents "Zero (absence of) clear speech."[46] If a user taps an icon representing a symptom, then a pop-up window shows that the user may be having a stroke, informs the user that it may be a stroke, and directs the user to call emergency services immediately. The user also has access to view the nearest hospitals and his/her location by the help of the Global Positioning System (a built-in function of smartphones).

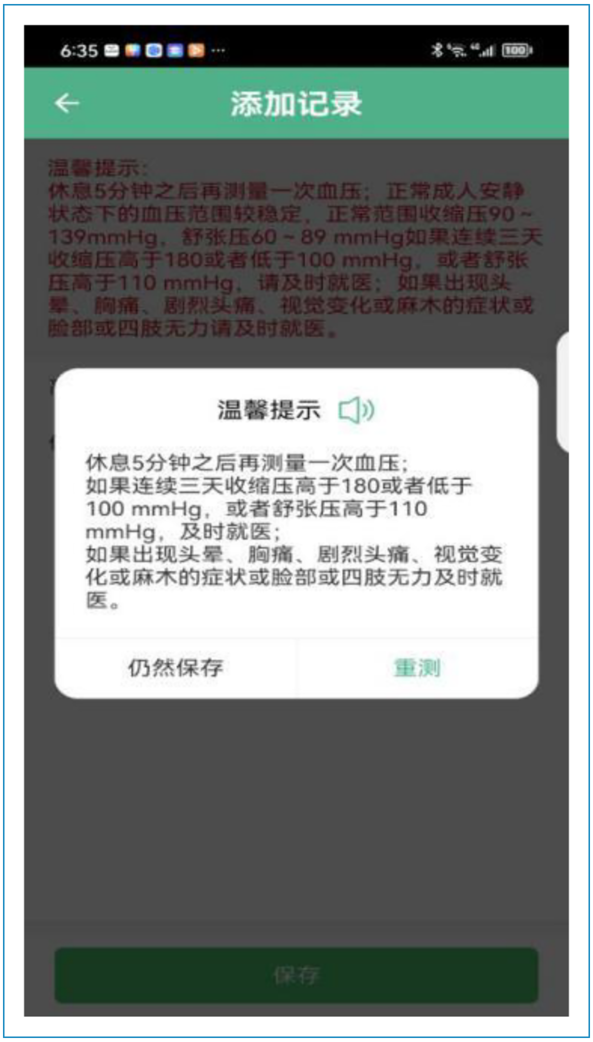

Figure 6. Example of a push notification in the app.

The app launches the care mode, which has large and clear words, vivid colors, good recognition, and large buttons for ease of use of older adult stroke survivors (Figure 7).

Alpha testing

Several minor flaws (e.g. wrong spelling) were identified by the content expert. In addition, the content expert suggested the addition of more information on hypertension and diabetes. The app expert gave several pieces of advice, such as using the same font size and color throughout the app. The issues encountered in the Alpha testing are summarized in Table 3.

Beta testing

One-to-one evaluation. All the three participants were satisfied with the app during one-to-one survey and provided positive feedback. The application usability fulfilled the criteria; for example, it is easy to use and has simple interface

Figure 7. Care mode effectiveness of the app.

design and appropriate color schemes as well as high-resolution graphics. No programming or technical errors undermined the use of the app based on the evaluation.

Small group evaluation. A total of 15 older adult stroke survivors participated including 10 men (66.7%) and 5 women (33.3%). The participants were aged 60 to 87 years, with an average age of 71.33 years. Eight (53.3%) participants had a primary school education or less; 46.7% lived with spouse; the majority had comorbidities (86.7%); and 66.7% of them were married. The mean total types of prescription medications per day was 3.73 (1.62), and the mean duration of stroke disease was 40.8 months (range 12–240 months). An overall UMUX score of 71.4 (SD 14.6) was obtained, which was higher than 68 on the SUS score, which is the minimum cut-off point for a usable system; this finding the good usability of OASapp as a mobile app. Based on Beta testing, older adult stroke survivors provided some suggestions regarding adjustments: information should be stepwise, brief, and short (e.g. presented as maximum three screens of text); choosing whether one would like to read or listen should be easily conducted; the language used in the app should be changed to reflect everyday user language, instead of academic or medical terminology; animations and illustrations should be used to create visual aids and substantiate the information in clear and engaging manner.

Discussion

Main final findings

The development of apps by using comprehensive, robust, and theory-based methods is critical to their success.

Table 3. Issues with Alpha testing.

Issue	Changes made to the app
Delay in medication reminding	Fast sync capability added
Dosage unit mg is not available	Put "mg" in dosage unit
Wrong spelling	Amending errors
Font size and color are not uniform	Using the same fonts in size and color throughout the app
Line spacing cannot be set in the body of health information	Glitch in system amended immediately
There is no information on hypertension and diabetes	Add information on hypertension and diabetes

OASapp was well accepted by the content expert (Alpha testing) and consumers (Beta testing). In this context, the usability of the app is critical in older adults with stroke because they have major setbacks in using smartphone apps compared with other adult consumers. Wildenbos et al.[47] reported that age is associated with normal physical decline (e.g. hearing or visual impairments), which poses a barrier to effective mobile device use. Four key aging barrier categories, namely, cognition, physical ability, motivation, and perception, can influence the usability of mHealth.[47] Operational and technical literacy are the major challenges for many older adults because they are still not as tech-savvy as the younger generation.[48] If the design accommodates age-related perceptual, cognitive, and motor changes, then the app may be more likely to be acceptable for older adults. A recent observational study underscored the pivotal role of a simplistic design and the incorporation of features catering to neurologic deficits when developing a mHealth app for post-stroke care derived from usability testing.[49] Previous research indicated that the complexities of older adults (with chronic conditions) and their disabilities are often overlooked and that many of the developed mHealth apps consist of many difficulties to understand features.[50,51] App functions that are difficult to use or understand might result in a significant decrease in usability. These factors are common problems and shortcomings of currently available stroke mobile apps. Based on our review of existing apps and systematic review of literature, most apps are not designed to cater to older adults.[18] Limited literature is available on the development of apps that improve medication adherence among older adult stroke survivors, and the present study should inform future researchers in this evolving field.

HBM and TAM provide a well-defined framework for app development. Based on the HBM constructs, perceived benefits, perceived barriers, self-efficacy, and cues to action are associated with app uptake intention.[52] During the development process, all these elements were addressed by health information in different formats (e.g. textual information, graphic presentation, or video). The stroke map component analyzes the user's risk for stroke and provides advice or recommended action. This component will strengthen the perceived susceptibility that an individual might have the risk of suffering from stroke. The app content and functionality were refined and focused using HBM. Furthermore, the perceived ease of use and usefulness can pose barriers to technology acceptance and universal access among older adults.[53] Additionally, Walrave et al.[52] reported a negative relationship between age and perceived benefits; thus, older potential users need to be more convinced of the app's benefits. TAM posits that higher perceived usefulness and ease of use results in more greater behavioral intention and actual use of the technology.[54] Therefore, we applied TAM to facilitate the development of OASapp. For example, we launched care mode, voice input mode, voice broadcast, and share mode through WeChat to ensure that the app is easy to use. HBM and TAM contributed to the successful development of the app. However, Mohr et al.[38] commented on the lack of theory and evidence to inform the design of development of most apps available to consumers. In general, our study provides an example on how the theory component was incorporated into designing a mHealth app. The results will have potential use and implication for developers in terms of incorporating theory in the development of health-related apps.

NGT was used to develop OASapp. In contrast to other NGTs,[30,55] where participants generate their list of attributes before the discussion and rank them afterward, the NGT in the present work compiled attributes from the literature review and presented them for discussion with the participants. Although the participants were not allowed to brainstorm before the discussion because of time constraints, they were provided with opportunities to voice their opinion on what the components should be and how to implement the program. NGT allows everyone in the group to contribute to the discussion. The NGT results showed that medication reminders, track BP/lipids/glucose, disease information, pharmacy information, and communication were the top five features voted by the participants. The ranking of these features highlighted that the group had a consensus on what is the important issue and the prioritization of app features. Our study confirms that the use of NGT is feasible and valuable for identifying important features about apps.

Despite the plethora of medication adherence apps, the majority of them were considered low quality.[56] Haase et al.[57] identified 30 medication-related apps that were written in English and summarized few ideal features from the top five applications (e.g. xNetwork, Mango Health, MyMeds, C3HealthLink, and HuCare). In the present study, we incorporated ideal features that could help patients take medications as prescribed. First, OASapp delivers medication reminders to promote medication adherence by using push notifications, alarms, and short-messaging service (SMS) reminders. Ahmed et al.[58] conducted a review of medication adherence apps available in repositories and found that very few of them (1.4%, 6/420) incorporated SMS reminders. Recent evidence suggests the significant effect of SMS reminders on improving medication adherence.[59,60] Additionally, OASapp can generate medication reminders for different medications for more than one user, including family members, pharmacists, and other healthcare providers. By involving different stakeholders in the patient's care journey, OASapp creates a more holistic and interconnected support system. This collaborative feature enhances communication and coordination among those responsible for stroke survivors' well-being. Several studies have revealed that support for stroke survivors from family members, pharmacists, and other healthcare providers plays a significant role in lowering the risk of stroke.[61,62]

OASapp also has a convenient feature that allows medication lists to include indications so patients are educated and make associations with each medication. Educating stroke patients about their medications is crucial, especially considering the complexity of their medication routines. OASapp empowers patients by offering information about the purpose of each drug, enabling them to make informed decisions and fostering a deeper understanding of their treatment plan. Finally, OASapp provides users the opportunity to add a picture to provide visual clues (e.g. to ensure correct medication is taken). For stroke survivors who may face cognitive challenges, visual cues serve as valuable aids in ensuring that the correct medication is taken. This feature goes beyond the typical functionalities of medication adherence apps and caters specifically to the unique needs of stroke patients. In conclusion, OASapp stands out from other medication apps with its SMS reminders, support for multiple users, medication indications, and visual cues. These features together offer a more personalized and comprehensive solution for stroke patients, addressing their unique challenges and promoting better medication adherence in this group. However, further research should be conducted to establish the clinical efficacy of the app.

Alpha testing showed a positive result, that is, the content developed met the requirement of the app. Moreover, the app expert involved in the testing assumed that the app was good and met the usability requirement. Overall, the Beta testers had positive feedback with respect to the usability of the mobile application. The usability score of the app was significantly higher than the minimum cut-off point for a usable mobile app; as such, OASapp is a usable mobile app for intended users. However, open-ended questions may be applied while utilizing UMUX on its own if unique problems should be refined with mobile applications. Mummah et al.[19] mentioned that without qualitative measures, one could not easily explain why people assigned a low, or even a high, score with respect to the usability of mobile applications. According to Sauro,[63] seasoned users continued to have higher SUS scores relative to first-time consumers. Thus, if the respondents were given more time and exposure to explore mobile applications, then the UMUX score may be higher. Further evaluation of different methodologies for usability testing could be included such as by those who have utilized the mobile application for some time.

Limitations and future work

One of the limitations of this project is the lack of a web portal for sharing patient-entered information with health care providers. Currently, patients have to share information to health care providers via WeChat. In the future, a web portal will be created to make data readily available to providers. We plan to take a series of measures to improve the next version of the app, including but not limited to, making and publishing OASapp operation guidelines on the official WeChat account platform, creating databases and decision rules to help users determine the normality of laboratory and diagnostic test results, and adding informative tips to the operation steps.

Another limitation is the limited number of participants who tested the usability of the current version of the app. About 80–90% of usability problems would be uncovered if 7 to 10 participants are involved.[64] Once the users have used the app for a period of time, they will have a better idea of what they want. We will create and distribute questionnaires to understand the specific needs of actual users and update the app in the next phase of this project.

We will further examine the effects of OASapp. More work is done in the commercial field than in the research field, which is quite logical due to the mercenary nature of businessmen. Parati et al.[65] suggested that the rapid growth of the commercial market has led to overabundance of apps that lack readily available evidence of their effectiveness. Ahmed et al.[58] indicated that robust evidence supporting the use of app-based interventions is necessary.

Conclusions

We developed and tested OASapp through mixed methods and iterative design to improve the medication adherence of older stroke survivors. The development and evaluation of OASapp highlights the important aspects of the creation process, which may be beneficial for researchers and medical professionals who aim to develop similar mHealth apps in the future. As a way forward, OASapp will be used in clinic trial to determine the effectiveness of it.

Summary table

What was already known on the topic

- Medication adherence among stroke survivors is problematic.
- Many medication adherence apps are currently available given the accessibility and widespread use of mobile phones; however, these apps are not specific to diseases, such as stroke.
- A theory-based app could stress and sustain health promotion behavior change; otherwise, the app's effectiveness could be limited.

What is this study added to our knowledge

- Reports on the design and development of a mHealth app, namely, OAS, based on the Health Belief Model (HBM) and Technology Acceptance Model (TAM) to improve medication adherence among older adult stroke survivors.
- mHealth apps, such as OASapp, are promising digital technologies for stroke survivors.
- Further research is needed to establish the clinical efficacy of OASapp so that it can be utilized to improve clinically relevant outcomes.

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