Design of a Mobile Application for Dietary Carein Chronic Kidney Disease

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Abstract

Chronic kidney disease (CKD) has become a global public health burden. With the popularization of mobile technology, the use of mobile health applications (mHealth apps) can effectively promote active patient participation in personal health management. To date, academic research has not examined user experience (UX) or opinions of the functions provided by CKD-related apps in depth. Toguide the design of CKD app, the design process consisted of interviews with patients and healthcare teachers, discussions with UX experts, and usability evaluation. The study identified the context and insights required for the design. For instances, the app could assist healthcare teachers in helping patients to solve daily dietary problems, and providing healthcare education information. The software could help elderly patients to acquire self-care abilities, understand their own physiological status and raise self-awareness concerning the illness. Finally, simplicity is an indispensable element of all CKD health apps, particularly those targeting users with relatively low electronic literacy.

Keywords: mobile application, mHealth, dietary care, chronic kidney disease.

1 Introduction

Chronic kidney disease (CKD) has become a global public health burden. While CKD has been shown to increase mortality rates and risk of cardiovascular diseases, the application of management strategies has been found to reduce end-stage renal disease incidence, CKD burden, and medical expenses (Jha et al. 2013). Through the provision of accurate medical and health education information, patients are able to understand the importance of disease awareness, increasing their willingness and ability with respect to self-care. Mobile health (mHealth) is expected to bea key factor in self-healthcare solutions for chronic diseases (Patrick et al. 2008; Strong et al. 2014). While health-related applications (apps)have become increasingly popular, research examining the development and evaluation of these apps is in its infancy(Dennison et al. 2013). Most apps that are targeted at consumers are not developed by health experts or researchers and do not examine behavior change theory or technology; therefore, they cannot correct content according to clinical guidelines for problematic conditions or behaviors(Breton et al. 2011; Chomutare et al. 2011; Cowan et al. 2013; West et al. 2012).

For example, in order to prevent and manage CKD successfully, patients' lifestyles should include a healthy diet, which should be personalized according to their renal function impairment and medical examination reports, developed to suit patient requirements following discussions with physicians and healthcare teachers, and able to account for sodium, potassium, calcium, phosphorus, and protein intake (Mitch & Klahr 2005).Previous studies have reported that patients who use IT to monitor exercise and manage chronic CKD achieved good results (Bennett et al. 2012; Cummings & Turner 2009; De Jongh et al. 2012; Downer et al. 2006; Eland-De Kok et al. 2011; Head et al. 2013);however, similar applications for renal disease are rare (Diamantidis & Becker 2014). Although greater knowledge is related to improvements in self-management behavior in chronic diseases, CKD patients are often dissatisfied with their ability to communicate with healthcare providers (Cavanaugh et al. 2009; Curtin et al. 2004; Dobbels & Duerinckx 2013; Kazancioglu et al. 2008) and unaware of their CKD diagnoses or the implications thereof (Greer et al. 2011; Tuot et al. 2011; Wright Nunes et al. 2011). In addition, CKD patients are normally elderly, with relatively low socioeconomic status and health literacy, and are rarely IT providers' target market.

With the emergence of healthcare technology, a large proportion of the CKD population is likely to be ignored (Diamantidis & Becker 2014). Until now, academic research has not discussed user opinions and experience of the function and technology of CKD-related apps in depth. In fact, a lack of patient-centered design leads to the inability to fulfill patients' needs effectively and results in failure to improve the quality of medical services via technology. Therefore, the present study aimed to design a mHealth app to assist CKD patients in establishing healthy lifestyles in accordance with user experience (UX). The study focused on (1) interviews with patients and healthcare teachers to identify users' core needs (implications of medical examination reports and diet management); (2) discussion with UX experts to design simple, user-friendly interfaces and interactive modes (with consideration of degraded mental and physical function in elderly patients); (3) acquisition of UX feedback, employing usability assessment to guide the design of CKD apps.

2 Methods

The present study was conducted in three parts: (1) UX design, (2) competitor evaluation, and (3) application design(Figure 1).

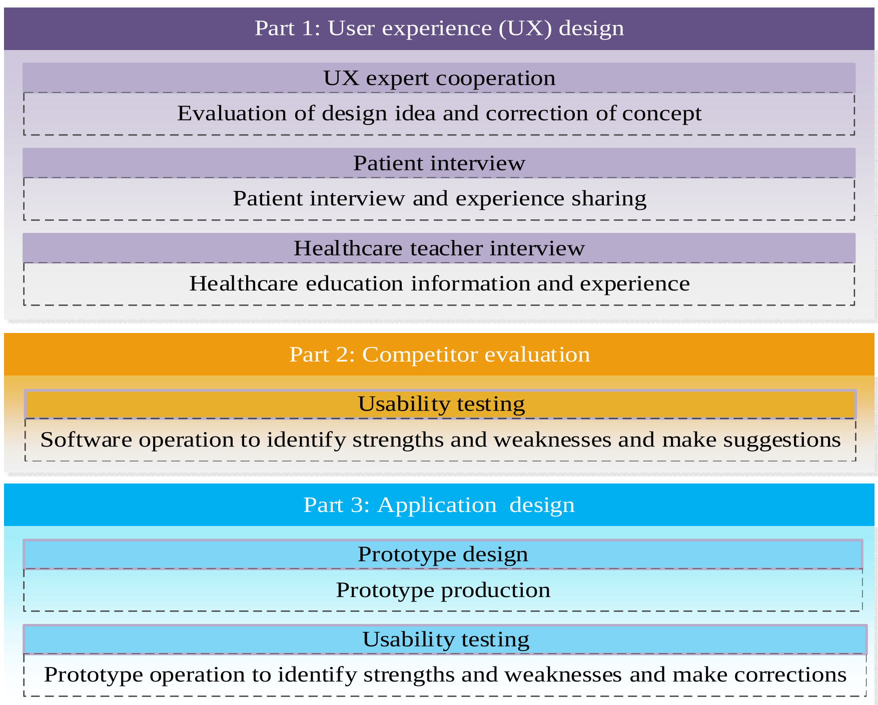

Figure 1: Research process

2.1 UX design

We collected information from existing CKD research to help us to understand the problems and methods involved and address patients' issues concerning exercise and diet. To form the app design concept for target users, the research team discussed the results and interviewed UX designers, healthcare teachers, and patients to summarize patients' and the healthcare teachers' needs.

2.2 Competitor evaluation

Having interviewed healthcare teachers, we realized that patients' diets were closely related to their medical examination reports. To perform competitor evaluation, we searched for apps related to dietary management and medical examination reports using the iPhone OS (iOS) and android systems. The "Taoyuan Health Plate" and "Kidney Appetite™" were used as competitor analysis apps for dietary management; "Hygea" and "Medical Examination Report" were used as competitor analysis apps for medical examination reports. The researchers designed three tasks (described in the results section) to test the usability of the apps. Thereafter, participants were asked to report their preferred apps and the apps' strengths and weaknesses and share their personal operation experiences. The researchers evaluated the data collected and sought the best practicesin terms of UX, which complied with usability. The feasibility of the function, theme, and operational mode provided by each app was analyzed, with a focus on designing an app easy to use.

2.3 Application design

The app prototype was designed and conducted for usability testing. Participants' opinions were used to determine their satisfaction with the accessibility of the app design. The analyses of the collected data were used to correct the prototype and program an app that fulfilled users' needs and was easy to initiate.

3 Results

3.1 UX design

Through two editions during the process, Kidney Guard was finally produced based on an investigation involving the researchers, UX designers, patients, and healthcare teachers. The usage contexts and insights required for the design and valuable opportunities were identified.

3.1.1 UX expert cooperation

In order to design an app that was consistent with the needs of CKD patients, we cooperated with three UX experts who came from industry to assist the research team in designing an app that was consistent with users' needs. During the meetings with the UX experts, we gradually incorporated UX into the app design concept and gained deep understanding of user-centered design, for which the key points are summarized in **Error! Reference source not found.**.

Table 1. UX expert cooperationsummary

Meetings	Team design concept	UX expert suggestion	Correction after discussion
First	1. The target users were patients with Stage I–V CKD 2. Long-term diet and exercise tracking to defer the deterioration of kidney disease 3. Establish internet community platform, which contains dieting method and healthcare education information provided by nutritionists and doctors, while patients share their experience in a virtual environment 4. Use the transtheoretical model (Prochaska& Velicer 1997) to change dietary and exercise habits	1. Start with user definition and usage scenarios 2. Narrow down the app coverage to focus on certain core values	1. Diet was relatively important to kidney disease patients at Stages IIIb and IV 2. The main population consisted mostly of diabetic patients and elderly individuals
Second	1. Postpone the course of the disease through diet	1. Suggestion to conduct user interviews to understand users' needs	1. Interviewed with healthcare teachers and patients 2. Connected the meaning of medical examination information with the correct method of dietary management
Third	1. Incorporated the transtheoretical model to change dietary and exercise habits	1. To find a suitable and novel presentation method 2. To address users' most important core issues using the simplest method	1. Deleted previous design containing the transtheoreticalmodel and simplified the interface and operational method 2. Incorporated medical examination report information 3. Compared and systematically analyzed medical examination reports and provided users' dietary suggestions
Fourth	1. Designed the simplest interface for elderly users 2. Provided personalized diet feedback information for users	1. The overall design should be simple and present displays with relatively large icons	1. Added the "diet shake" function 2. Usability testing 3. Produced the final version of the prototype

3.1.2 Patient interview

In order to design an app that was consistent with UX, the research team interviewed CKD patients and clarified topics in the concept, which were closely related to design. The interviews are summarized in **Error! Reference source not found.**.

Table 2. Patient interview summary

Interview topics	Pre-interview concept	Post-interview concept correction
Disease stage of interviewed population	All Stage I–V patients	Mostly Stage IV and V patients who underwent kidney dialysis
Age of interviewed population	Approximately 40–60 years	Older than 50 years
Establishment of E-patient community	A platform for experience exchange	Unwilling to inform others of issues related to kidney disease
Level of fear over disease	Patients would try hard to improve conditions even at an early stage	The degree of fear varied between disease stages
Cause of disease	Unclear cause of disease	Patients did not know why they had developed the disease
Healthcare education information spreading	Through internet search	Healthcare education information from healthcare teacher during checkup
Important information	Diet, exercise, monitoring, and healthcare education	Diet and healthcare education
Changing dietary habits	Patients improved dietary habits according to healthcare education information	Patients corrected dietary habits after feeling unwell after eating certain foods

3.1.3 Healthcare teacher interview

In order to understand users' needs, we consulted healthcare teachers regarding diet-related CKD information. Following discussions with three healthcare teachers, we found that CKD diet was not distinguished by the disease stage. In contrast, diet was adjusted according to the parameters in medical examination reports (i.e., sodium, potassium, calcium, phosphorus and protein levels). The interviews are summarized in **Error! Reference source not found.**.

Table 3.Healthcare teacher interview summary

Interview topics	Pre-interview concept	Post-interview design suggestion
Establishment of medical examination parameters	All parameters in medical examination reports were to be included in the software	Sodium, potassium, calcium, phosphorus, and protein levels in medical examination reports were used as the basic parameters for screening users' diets
Medical examination design concept	Visualization to inform patients regarding the meaning of medical examination data	To compare differences in medical examination reports. If the values were lower than those of the previous report, they would be shown in red; otherwise, they would be shown in green
Diet interface design	In terms of the diet interface color, red and green were used to indicate whether a certain food should be consumed	Presentation with smiling and frowning faces: a smiling face represented that the food choices would not impose a burden on the body; a frowning face represented that the food choices would impose a burden on the body

3.2 Prototype design

To allow closer inspection of users' factual needs, the researchers discussed and planned the design with patients, healthcare teachers, and UX designers and performed competitor product analysis of related apps, to pursue the most suitable design. It took a year to yield the final prototype version (i.e., Kidney Guard), which contained (1)medical examination report, (2) dietary management, (3) dietary feedback, and (4) the "diet shake" function.

3.2.1 Medical examination report

Following each medical examination, patients entered details related to dietary management into the medical examination report manually; sodium, potassium, calcium, phosphorus, and protein levels in medical examination reports were used as the basic parameters for screening users' diets. Kidney Guard planned a personalized dietary specification based on the information. To notify patients of their physiological status, the app presented differences in current and previous medical examination reports.

Values that were lower, higher, and the same, relative to those of the previous report, were shown in red (i.e., alert), green (i.e., safe), and black (i.e., fair), respectively. In addition, by accessing medical examination standards, users were able to determine whether their current medical examination parameters were consistent with those standards.

3.2.2 Dietary management

The app utilized images and illustrations instead of text to assist patients in obtaining healthcare knowledge and dietary information. In addition, once details concerning the food that was to be consumed were entered and confirmed, the system created a record automatically. The system keeps the diet information to give feedback on patients' diet.

3.2.3 Dietary feedback

Kidney Guard compared patients' dietary specifications and intended diets. When the latter exceeded dietary recommendations, the app would provide feedback regarding the nutrients (e.g., calcium) that had been over consumed. The easily identified visual messages encouraged patients to make healthy decisions; red mushroom heads and frowning faces represented dangerous food choices, while green mushroom heads and smiling faces represented healthy choices. The app also provided users with reasons for avoiding consumption of these foods, which improved dietary health knowledge.

3.2.4 Diet shake

The "diet shake" is a feature of Kidney Guard and provides variety and fun in patients' diets. When users exhausted their own ideas regarding what to eat or which foods could still be eaten, they could shake their mobile phones, which constituted the "diet shake"; this provided details of randomly chosen food and drink consistent with the dietary specifications for the day. If patients did not like the suggestion, a second shake would produce details of a different dish. Whenever users chose and confirmed the suggestion, a dietary record was created automatically.

3.2.5 Summary

Effective dietary management could defer the progression of disease. In this study, interview results indicated that patients were sensitive to uncertainty in diets, and the majority of the questions posed to healthcare teachers concerned dietary health education. Following a number of concept corrections, the final design focused on CKD patients' dietary management. Specifically, prior tousers' consumption of food and drink, the app screened for unhealthy and high-risk diet, which helped patients to manage their own health. Further, by incorporating hearing, touch, and chromatics, the design could help elderly patients to understand personal health status more easily, establish a route to health, and become guardians of their own health.

3.3 Usability testing

3.3.1 Participants

The test included 15 participants, including eight men and seven women aged 20–60 years. One, two, and twelve participants had no experience, less than a year's experience, and more than a year's experience of using smart phones, respectively. We designed three tasks to test the usability of the apps. The time participants took to complete tasks and the numbers of errors were recorded. Thereafter, participants were asked to report the apps' strengths and weaknesses and share their personal operation experiences.

3.3.2 Task 1: choosing an appropriate diet

The first task was designed to determine whether a specific diet to be consumed was appropriate for users. Participants indicated that Taoyuan Health Plate used individual ingredients (e.g., egg) in nutrition recording, which was inconsistent with normal dietary patterns (e.g., omelet). On the other hand, Kidney Appetite™ reflected actual diet patterns closely, whereas the items were not ordered alphabetically and were presented in English; therefore, searching was time consuming. In contrast, Kidney Guard returned immediate visual messages after entering details of food items; participants found it easy to understand recommendations as to whether the diet could be consumed. In addition to the task complete time and the numbers of errors, feedbacks on Kidney Guard are also shown in **Error! Reference source not found.**.

Table 4. Task 1 results			
Usability indicator	Testing software		
	KidneyGuard	KidneyAppetite™	Taoyuan Health Plate
Completion time (seconds)	28.3	54.55	32.11
Error (frequency)	0.53	1.64	0.56
Participant number	Feedback on KidneyGuard		
01, 03	I hope that the mushroom-shaped buttons for deciding whether food can be consumed can be combined with text. Informing the user about banned food items using a ribbon-shaped icon is too unclear. I hope that a more obvious prohibition icon is used.		
02	I suggest replacing typing with pictures, which would simplify the process.		
04, 09	There was no need to have an interface with the image of a cook. Changing directly to the diet plate is fine, and having an additional layer of clicking and searching was unnecessary.		
10	Entering food and drink details was not too difficult, but I would hope for a handwriting function, which would simplify use. The mushroom-shaped buttons could be a bit smaller.		
11	I had no experience of using smartphones and had to be accompanied by a typist for data entry. I also experienced some difficulty in learning, but I think this software is very convenient compared to having to remember a lot of useful and useless information.		

3.3.3 Task 2: checking medical examination reports

The second task asked participants to look for parameters in the medical examination report. The task was designed to help users to acquire the values in their medical examination report. Participants indicated that the interface design of Medical Examination Report was too simple, and the icons lacked text explanation; therefore, users were sometimes unaware that the icons were buttons. On the other hand, Hygea recorded all information contained in the medical examination reports. However, the dropdown menu was too long, and users had to search a few times to locate the correct information. The participants generally considered the Kidney Guard interface design simple and clear. By simply sliding the main interface to the right, users could locate current medical examination reports very easily and compare them with previous reports. The task complete time, numbers of errors and feedbacks on Kidney Guard are shown in **Error! Reference source not found.**.

Table 5. Task 2 results			
Usability indicator	Testing software		
	Kidney Guard	Hygea	Medical Examination Report
Completion time (seconds)	3.8	43.11	25.81
Error (frequency)	0.07	0.89	0.82
Participant number	Feedback on Kidney Guard		
05	The font used in the medical examination data units was too small and should be enlarged. If the data unit appearance had no big impact, the current presentation could be retained.		
10	In terms of value comparison, the idea of using red for elevated values and green for lower values is great. This could make the users feel that their effort was worthwhile.		
15	The information in the medical examination report needs to be dated, to show when the report was made.		

3.3.4 Task 3: checking medical examination indexes

The third task asked participants to check whether their current medical examination parameters were consistent with the standards. The task was designed to help users understand their physiological status and raise self-awareness concerning the illness. Participants indicated that while Hygea could clearly present the index criteria, there were a relatively more number of steps to complete the task, which affected the completion time. Medical Examination Report, on the other hand, required first the input of the indexes, before the criteria could be found. When using Kidney Guard, the participants only needed to slide the main interface to the right to determine if the medical examination report complied with the standard. Most participants had not many opinions on the process of completing the task. The task complete time, numbers of errors and feedbacks on Kidney Guard are shown in **Error! Reference source not found.**.

Table 6.Task 3 results

Usability indicator	Testing software		
	Kidney Guard	Hygea	Medical Examination Report
Completion time (seconds)	10.9	26.44	37.82
Error (frequency)	0	0.44	0.64
Participant number	Feedback on Kidney Guard		
01	When deciding if the medical examination indexes complied with the standard, there was not much point in presenting the most recent medical examination report indexes. However, this can be kept and there is no need to change.		

3.3.5 Prototype correction

The sections that were corrected according to participants' suggestions are shown in
Figure **2**. In terms of dietary feedback, the original ribbon icon (
Figure **2**-a) advising against consumption was replaced by a prohibition design (
Figure **2**-b). The sizes of the mushroom design buttons, which indicated whether food should be consumed, and the text were reduced. In the medical examination report section (
Figure **2**-c), the dates on which reports were created were included to assist users in understanding the report records (
Figure **2**-d).

Figure 2: Prototype correction

4 Discussion

The main aim of the study was to design a self-care app for CKD that was consistent with UX. We used a user-centered design concept and interviewed healthcare teachers, CKD patients, and UX designers. The four parties worked together to plan the app, and attempted to understand the ideas and thoughts of the others from different perspectives to identify problems and suitable means of solving health issues that were most problematic to CKD patients.

The practical values and significance of the study included the following. (1) Prior to consuming food and drink, users could use the app to determine whether a certain food item could be consumed. (2) The app could assist healthcare teachers in helping patients to solve daily dietary problems, and providing healthcare education information. (3) Theapp could help elderly patients to acquire self-care abilities. (4) The comparison of medical examination report information and criteria could help patients to understand their own physiological status and raise self-awareness concerning the illness. Kidney Guard records CKD patients' meal details and calculates the amounts of nutrients already consumed and remaining each day. Therefore, users were spared the burden of analyzing and understanding medical examination report data themselves. Based on users' dietary intake, the app provides users with personalized healthcare education information, increasing their awareness concerning dietary choices.

In addition, Rabbi et al. (2015)posited that personalized suggestions should consider the importance of users' lifestyles and preferences. Therefore, for CKD patients, the provision of a number of randomly chosen feasible dietary plans, within an allowable suggested intake range, and allowing users to decide whether to accept the diet was necessary for successful acceptance of personalized suggestions. This type of personalized suggestion is better suited to patients' needs, relative to singular dietary suggestions, and helps patients to improve their dietary management and self-care abilities. Research examining the application of various theories for the establishment of health behaviors to help patients with chronic diseases to improve their health has gradually drawn increased attention. This study attempted to apply the Trans theoretical model in changing users' unhealthy habits. However, following interviews with healthcare teachers and UX designers, we decided to adopt dietary intake, which was the issue that concerned users most, as the main functional design and use the simplest method to address the issues that were most important to patients. The achievements of previous scientific research, such as goal-setting theory (Locke & Latham 1990), feedback and behavior control (Carver & Scheier 1998), and means of integrating science and technology to promote personal health and quality of life, are still worth in-depth examination.

Determination of the theories and suggestions that are most feasible for facilitating self-care in CKD patients is required. In contrast, some research has shown that simplicity, high effectiveness, and pleasure affect the sustained use of smartphone apps (Verkasalo et al. 2010). Laborious and cumbersome functions are very likely to cause negative effects. Simplicity is an indispensable element of all CKD health apps, particularly those targeting users with relatively low electronic literacy (Diamantidis & Becker 2014). Challenges of future research include the inclusion of attractive and effective behavior management technology in apps while maintaining relatively low user burden (Dennison et al. 2013). Further studies should be conducted to determine whether the simple design proposed in this study could increase patients' awareness of self-care, and clarify whether combining technology and the theory of behavior change models would assist patients in establishing healthy habits.

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