



Design and Implementation of a Web-Based Self-Care Application for Patients with Kidney Stone Treated with Extracorporeal Shock Wave Lithotripsy

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Abstract

Background: The prevalence of kidney stones reduces the patients' quality of life and imposes high costs on patients and health care system. Extracorporeal shock wave lithotripsy is a safe procedure to treat urinary stones. Appropriate strategies such as self-care programs can effectively reduce the prevalence and recurrence of this disease, and increase quality of life, save costs, and prevent diseases by increasing patient participation. The aim of this study is to design and implement a web-based self-care application for patients with kidney stones undergoing extracorporeal shock wave lithotripsy.

Methods: This paper is an applied study and was performed in Sabalan Hospital in Ardabil affiliated to the Social Security Organization of Iran in three stages including needs assessment, design and evaluation. For needs assessment and application design, a questionnaire was designed by searching library resources. The questionnaire was completed by clinical specialists and specialists in health information management and information technology. Then, based on the approved information elements and capabilities, a web-based self-care application was designed. The usability of the designed program was evaluated with the participation of 20 users.

Results: The results of the survey showed that the experts confirmed all the identified items and components, and considered them necessary. Users rated the usability of the self-care program at a good level with an average score of 7.9 out of 9.

Conclusion: The usability of the self-care application was satisfactory to users in various areas of overall application performance, screen, terminology and information, learning and general impressions.

Keywords: Humans, Information technology, Iran, Kidney stone, Lithotripsy

Introduction

Kidney stone disease is the third most common, painful and costly problem among diseases of urinary system after urinary tract infections and prostate diseases in urology clinics (1). Kidney stone affects about 5 to 12 percent of the world's population during the most active and productive period of their lives between the ages of 20 and 50 (2). Various factors such as age, gender, family history, climatic conditions, nutrition, as well as economic and social status are effective in the prevalence of this disease (3). Severe pain, obstruction and recurrent infections, and efficiency reduction are adverse outcomes of kidney stone disease (4,5).

The prevalence of kidney stones varies in different countries. The prevalence of this disease is reported to be 1-5% in Asian countries, 5-9% in European countries and 12% and 13-15% in Canada and the United States, respectively (2). The prevalence of kidney stones in Iran is 5.7% (6.1% in men and 5.3% in women) (3). It is worth mentioning that Iran has the highest percentage of kidney stones among West Asian countries after Saudi Arabia and Turkey (6).

Today, Extracorporeal Shock Wave Lithotripsy (ESWL) is recognized as a common and non-invasive method in the treatment of kidney stones (7). In this method, high-energy sound waves from outside the body are used to destroy kidney stones (8). Large stones are broken down and passed through the urinary tract. ESWL has shortened the hospitalization time of patients and reduced the recovery time and patients' discomfort.

According to research (3,9), complications such as abdominal pain, damage to adjacent tissues, ureteral obstruction, hematuria, infection, cardiac arrhythmia and dialysis may occur following the use of extracorporeal lithotripsy. The recurrence rate of kidney stone formations is estimated between 10 to 23% in the first year, 50% in the next 5 to 10 years and 75% in 20 years after lithotripsy (10). Prevention of stones recurrence is still a serious problem in patients' health (11). It requires a better understanding of the mechanisms involved in stone formation (12). Kidney stones are associated with an increased risk of chronic kidney disease (13), end-stage renal failure (13,14), cardiovascular disease (13), diabetes and hypertension (15). In order to control and identify the mentioned

complications as well as early detection of clinical symptoms, it is necessary to perform counseling, self-care education and continuous follow-up of the patients' post-discharge to continue care and improve the quality of life. A patient who has been trained and has acquired the necessary information and knowledge about self-care in the post-discharge period can detect changes in symptoms and onset of complications and seek health care sooner than an untrained patient (16).

The continuity of care as a kind of coordination between patients and hospital is considered important and makes it easy to transfer the patient between the hospital and home. This will reduce the patient's anxiety and bring them to the highest level of health or activity. One of the key activities to achieving care continuity is to design a m-Health self-care application as a wide range of time-limited services (17,18). It is possible to prevent the mentioned complications by diagnosing the patient's educational needs and designing an appropriate self-care application with features such as medication, healthy diet, physical activities, individual counseling for patients and their monitoring (18). Researches (19,20) show that educating patients to discharge and provide health care services at home as a team can be very effective in reducing health care costs in the country.

Over the past 20 years, mobile technologies have revolutionized the diagnosis and management of urinary stone (21). Various programs in the field of kidney stones have been developed with different approaches such as strengthening hydration, diet modification, follow-up of drug use, and follow-up of symptoms with the aim of managing urinary stones (22). Many mobile applications are now designed to track water consumption. Most of them have several features in common: manual entry of liquids, notifications for rapid receipt of fluids, graphical representation of water consumption trends and providing feedback (22-24). Ureteral Stent Tracker allows users to scan a stent barcode to instantly create a file with a scheduled stent extraction date. The stent database can then be controlled via the program's visual dashboard (25). Mobile ultrasound scanners, which can be paired with smartphones, have tremendous potential for detecting and managing kidney stones, especially in remote or resource-scarce

areas. Butterfly IQ and Philips Lumify are the latest ultrasound scanners that can be paired with smartphones (22). The Hydriney mobile app allows the patient to use it as a “personal app” for kidney stone disease. Hydriney has innovative features to help improve life with kidney stones disease (26). The StoneMD application provides a list of foods (calcium, oxalate, and citrate) (21).

Although the use of ESWL has reduced the hospitalization and recovery time of patients, prevention and control of possible complications require empowerment of the patients. For this reason, and due to the high cost of this disease and the growing trend of its prevalence, it is necessary to design a self-care application with the aim of effective medical services, increasing the quality of life, and reducing the costs and recurrence rate of kidney stone. Despite the high prevalence of kidney stones in Iran and in the Middle East, no experience of using mobile-based self-care application for patients with kidney stones treated with ESWL has been reported in the available literature so far. This study designs and implements a web-based self-care application for patients with kidney stones undergoing extracorporeal lithotripsy treatment due to the importance of care continuity, increasing self-efficacy and patient’s self-care. The proposed self-care application provides a wide range of up-to-date knowledge and programs to reduce postoperative complications and increase the quality of life.

Materials and Methods

The present study is an applied research that aims to design and implement a web-based self-care application for patients with kidney stones undergoing extracorporeal shock wave lithotripsy treatment. Patients provided informed consent prior to inclusion in our study, which was approved by the ethics committee of Tabriz University of Medical Sciences (IR.TBZMED.REC.1398.1223). The research community includes urologists, health information management experts, information technology experts and patients referred to lithotripsy department of Sabalan Hospital in Ardabil. Ardabil Sabalan Hospital is the largest provider of medical services affiliated with the Iranian Social Security Organization in Ardabil province. The ESWL department has been

operating since 2018 with the equipment of Dornier lithotripter system. This research has been designed and implemented in three steps including formulation of the required components, application design and evaluation. The flowchart of the proposed application is shown in figure 1.

Step 1: Developing the effective requirements and capabilities in the web-based self-care application

Required data elements and capabilities of the application were identified and extracted with a comprehensive review of the operating instructions, guidelines, medical records and referred to lithotripsy department. By summarizing, integrating and

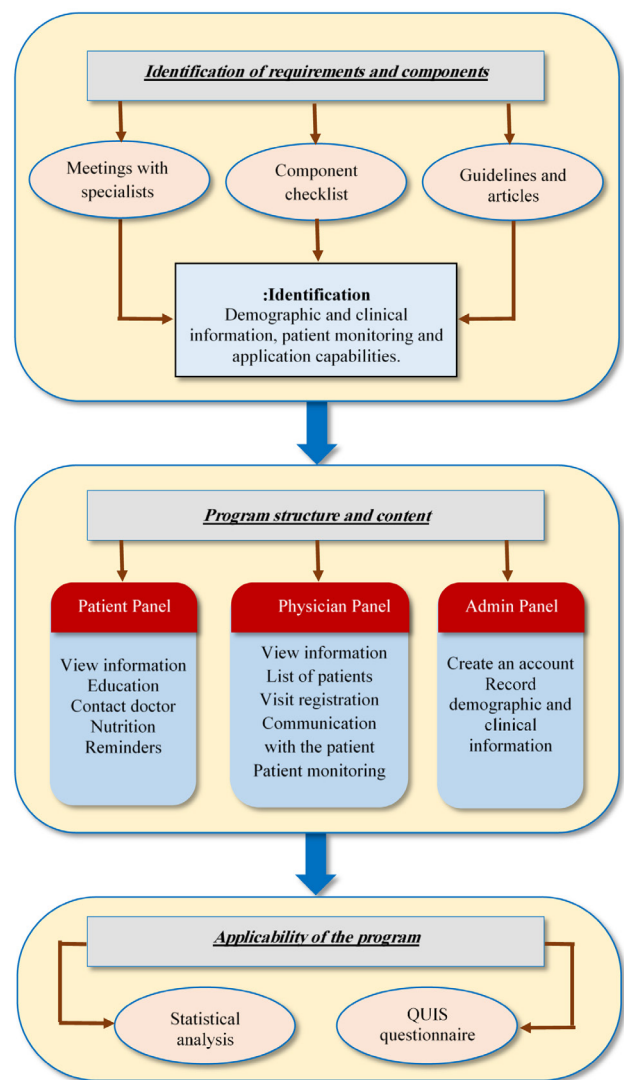


Figure 1. Flowchart of the proposed web-based self-care application.

prioritizing the extracted requirements, as well as consulting with clinical specialists, a questionnaire was designed with 64 questions on a 5-point Likert scale (strongly agree to strongly disagree). The questionnaire consisted of four main sections: demographic information (15 questions), clinical information (22 questions), patient monitoring (14 questions) and application capabilities (13 questions). At the end of each section of the questions, an open-ended question was considered to add the items by the respondents. The reliability of the questionnaire was calculated with Cronbach's alpha of 0.94.

Then, urologists, health information management and information technology experts commented on the requirements of the program in the form of a researcher-made questionnaire. The questionnaire was given to the members of the research community in person as much as possible and was collected after completion. The results of the survey were analyzed using descriptive statistics and frequency distribution report. Based on the scores given by the participants in the study, the frequency and average scores for each data element were calculated. Then, considering that the highest possible score for each data element was 5, half of this number was considered as an average score for each data element. As a result, each section of the questionnaire that had an average of at least 2.5 or more was regarded as a necessary section. If a new data element was suggested by at least 40% of the respondents in the open question section of the questionnaire, the data element would be used in the design of the program.

Step 2: Designing the content and structure of the web-based self-care application

In order to determine the infrastructure of the self-care application, a number of meetings were held with digital technology experts. Based on the requirements identified in the first phase, the most appropriate model hardware, software and database were selected. In designing the self-care application, criteria such as simplicity, accessibility, flexibility, interaction between the patient and the treatment staff and creating a database were considered.

Step 3: Evaluating the usability of the web-based self-care application

After implementing the self-care application under the supervision of clinical specialists, with the provision of initial training and sufficient explanations by the researcher, the program was provided to the medical staff and patients referred to Sabalan Hospital in Ardabil for treatment with ESWL. The selection of patients was done by easy access method so that users should have a smartphone and be sufficiently aware of the use of mobile applications. The self-care application was used by the patients for at least 10 days. Then, users' opinions about the usability of the program were collected by using the standard usability and Questionnaire for User Interaction Satisfaction (QUIS) (27). As a standard questionnaire, QUIS includes 27 questions related to the evaluation of usability and user satisfaction. This questionnaire consists of five sections: overall software performance, terminology and information, learning and (6 questions), screen (4 questions), software terminology and information (6 questions), learning (6 questions) and general impressions (5 questions). Each question has an answer with a score of zero (minimum capability and satisfaction) to nine (maximum capability and satisfaction).

The data was analyzed through IBM SPSS software. Through this software, the frequency of the participants' answers to the questionnaire's questions was presented. Data were analyzed using descriptive statistics (mean, variance and standard deviation).

Results

Information elements and capabilities of the application were extracted from a review of 17 articles related to the research. The demographic characteristics of the respondents are described in table 1. Based on the findings of the needs assessment questionnaire, all the extracted data elements with an average score higher than 2.5 were identified as essential. Among the information elements of the demographic section, gender and age had the highest mean (score 4.9). In the clinical section, stone location, stone size, number of stones, type of stone, history of stone excretion, and frequency of stone recurrence were considered absolutely necessary by all the participants. In the disease monitoring section, hematuria had the highest mean (score 4.9) and familiarity with kidney stones and program guide had the highest score (score 5) in

Table 1. Frequency of demographic data of the respondents in the needs assessment stage

| Gender | Age (year) | | Education | Experiences | | | |
|--------|------------|-------|-----------|-------------------------------|-----|-------|-----|
| Man | 60% | 20-30 | 20% | Urologist | 30% | 0-5 | 30% |
| Woman | 40% | 30-40 | 30% | Information Technology | 30% | 5-10 | - |
| | | 40-50 | 40% | Health Information Management | 40% | 10-15 | 10% |
| | | 50-60 | 10% | | | 15-20 | 40% |
| | | | | | | 20-25 | 20% |

the program capabilities section.

According to the identified requirements and capabilities in the first step, a user case diagram was drawn by IBM Rational Software Architect software and Unified Modeling Language (UML) (Figure 2). The initial design of the wireframe was done using WireframeSketcher software. Based on the MCV model in Microsoft Visual studio 2019 software and Structured Query Language (SQL) Server 2016 database, the web-based self-care application was designed in three sections: admin panel, physician panel and patient panel.

After extracorporeal lithotripsy, access and

registration of the urologists and patients with kidney stones is done by the admin. The application in the patient panel provides capabilities such as viewing and editing the personal information, recording the symptoms and complications after lithotripsy, recording the daily water intake, recording urine pH and volume, familiarity with kidney stone disease and a variety of results, nutrition appropriate to the type of kidney stones, activating the sending of reminders, contacting the treating physician and reporting to the patients. Urologists in the panel of physicians will be able to view the list of their patients and information recorded by patients after lithotripsy, communication with the patient in the form of messages and notes, determining the time of face-to-face visit, recording actions taken during face-to-face for the patient and recording lithotripsy results.

An example of a self-care application pages for patients with kidney stones undergoing extracorporeal lithotripsy is shown in figures 3-6.

The application was used by 20 users. 18 of the users were kidney stone patients who were treated with extracorporeal lithotripsy, and 2 others were urology specialists. With the participation of 20 users and the cooperation of the lithotripsy department of Sabalan Hospital in Ardabil, the self-care application was evaluated using a standard questionnaire to assess the usability and satisfaction of QUIS users. Among the 20 participants in the present study, men (55%) were more likely than women (45%) in terms of gender. Majority of the participants were in the age range of 40-50 years (50%) and were more educated than those with a bachelor's degree (40%). In this study, sampling was conducted by convenience sampling.



Figure 2. User case diagram of the proposed web-based application.



Tabriz University of Medical Sciences

Self-care Application for Patients with Kidney Stone Treated with ESWL

Welcome

Enter your login data

Username

Password

Remember password

[Forgot password?](#)

Log in

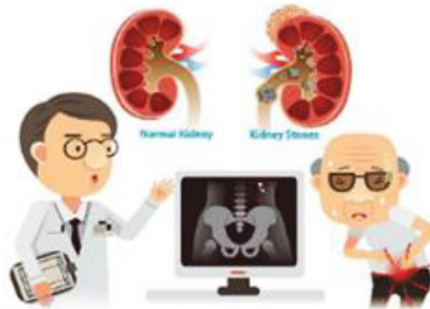


Figure 3. Login page.



Figure 4. Admin panel.

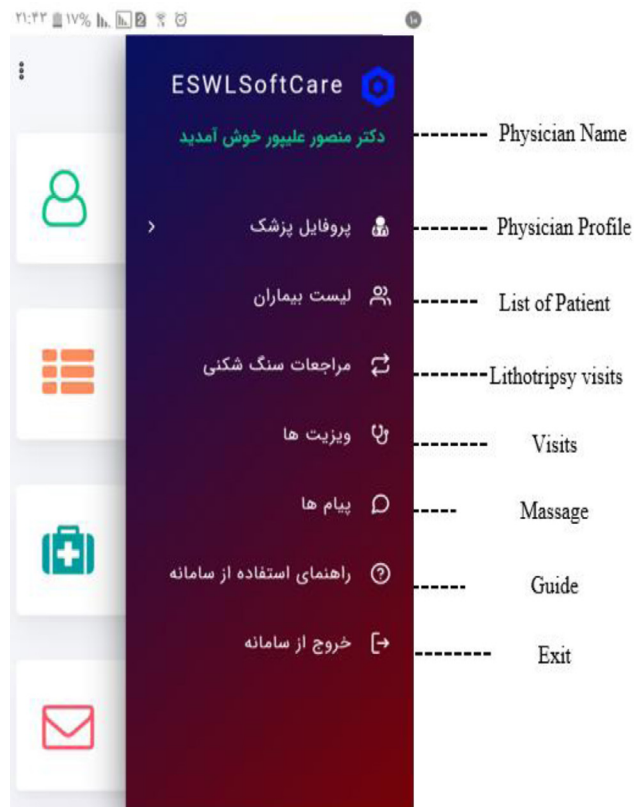


Figure 5. Physician panel.

Stone breaking is done by shock waves and small particles are excreted through the urinary system, mainly within 1 week to 10 days after stone breaking. Therefore, after 10 days, evaluation was done for three months. Users' views on the usability of the self-care application were collected in five areas: overall software functionality, screen, idioms and

information, learning capability, and overall program capabilities. The QUIS questionnaire was designed based on the nine-point Likert scale. Each question had an answer with a score of zero to nine. Scores were classified as follows: zero to three as poor, 3.1 to 6 as intermediate, and 6.1 to 9 as good. The results of user surveys were analyzed and evaluated using

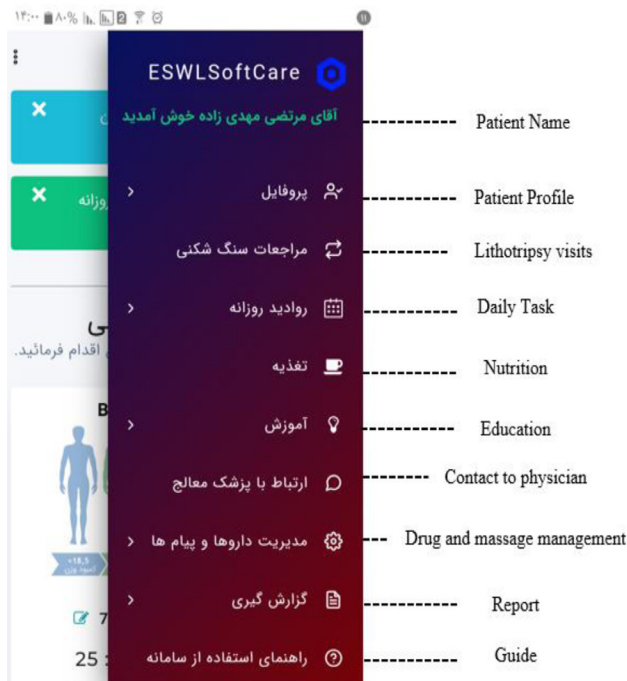


Figure 6. Patient panel.

descriptive statistics such as mean, variance and standard deviation. According to the results obtained in Tables 2 and 3, as well as figure 7, the summary and general average of users' views on the applicability of the application was 7.99 and evaluated at a good level.

Discussion

In accordance with the studies conducted with the aim of designing a self-care application to control tuberculosis (28), Acquired Immunodeficiency Syndrome (AIDS) (29) and heart failure (30), the

present study identified demographic data, clinical data and application capability. Since the present study is specifically designed for patients treated with extracorporeal lithotripsy, the disease monitoring section identifies possible complications such as hematuria, fever, and hypertension after crushing.

Akand *et al* (31) conducted a study to develop the Retrograde Intrarenal Surgery (RIRS) information registry system for patients with kidney stones in Turkey in 2019. They extracted and categorized the information into three sections before operation, during operation and postoperative. In agreement with the approach of Akand *et al*, in the present study, the data elements were categorized into data before lithotripsy (sex, weight, height, history of kidney stones, previous treatment method, family history of kidney stones, comorbidities, identification method of stone location, exact location of stone), data related to during lithotripsy (stone apoptosis, type of anesthesia) and data related to postoperative lithotripsy (drugs being used, postoperative complications, follow-up of stone removal).

In designing of the kidney and urinary tract stones registry program (Registry for Stones of the Kidney and Ureter-ReSKU), the necessary variables and data were assessed in four main sections: the necessary variables for registering a new patient, the variables related to the operation, the necessary variables for postoperative follow-up and the follow-up variables (32). In accordance with the design and needs assessment process of the ReSKU registry program, in this research, the following has been considered: data

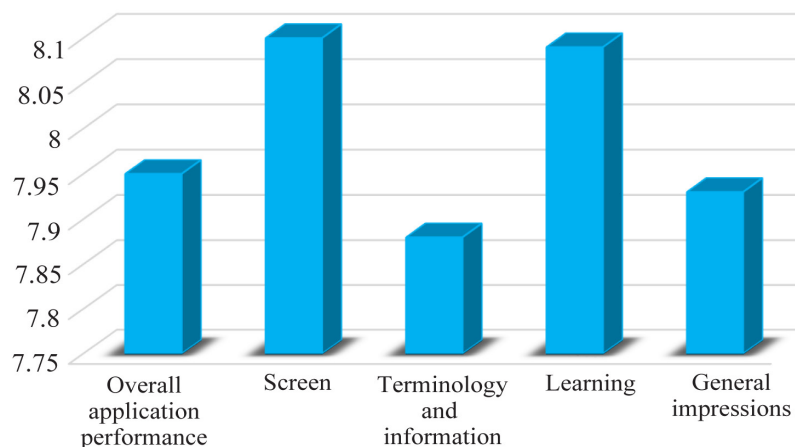


Figure 7. Average ratings by users on usability of the web-based self-care application.

Table 2. Users' viewpoint evaluation on the self-care application

| Features | | Indicator | | |
|---------------------------------|--------------------------------------------------------|-----------|--------------------|----------|
| | | Average | Standard deviation | Variance |
| Overall application performance | General function of the application | 8.2 | 0.46 | 0.68 |
| | The difficulty of working with the application | 8.4 | 0.64 | 0.8 |
| | How do you feel about using the application? | 8.1 | 0.56 | 0.77 |
| | Overall application design | 8.1 | 0.49 | 0.7 |
| | Continuous work with application | 7.8 | 0.86 | 0.93 |
| | Application configuration capabilities | 7.1 | 2.29 | 1.51 |
| Screen | Readability of the letters on the screen | 8.05 | 0.95 | 0.97 |
| | Easily perform the tasks with specific phrases | 8.3 | 0.61 | 0.78 |
| | Organizing information | 8.2 | 0.76 | 0.87 |
| | Screen sequences | 7.85 | 1.03 | 1.01 |
| Terminology and information | Use terms in the application | 7.85 | 0.93 | 0.96 |
| | A set of terms related to working with the system | 8.05 | 0.95 | 0.97 |
| | Location of messages on the screen | 8.5 | 0.25 | 0.5 |
| | Message to record essential data | 7.55 | 1.05 | 1.02 |
| | System messages regarding the completion of tasks | 7.95 | 1.05 | 1.02 |
| | Application error messages | 7.35 | 1.73 | 1.32 |
| Learning | Learning to work with application | 8.4 | 0.44 | 0.66 |
| | Discover the application features with trial and error | 8.05 | 0.85 | 0.92 |
| | Saving names and use the features | 7.8 | 1.26 | 1.12 |
| | Performing the tasks quickly and easily | 8.2 | 0.76 | 0.87 |
| | On-screen help messages | 8.35 | 0.73 | 0.85 |
| | Application usage guide | 7.75 | 2.29 | 1.51 |
| General impressions | Application speed | 8.05 | 0.55 | 0.74 |
| | Application availability | 7.65 | 1.93 | 1.39 |
| | Multiplicity of application capabilities | 8.3 | 0.51 | 0.71 |
| | Correction of user errors | 7.55 | 0.75 | 0.87 |
| | Designing to suit different users | 8.1 | 0.79 | 0.86 |

Table 3. Evaluation of the usability and patients satisfaction with self-care application

| Phrase | Average | Standard deviation | Variance |
|---------------------------------|---------|--------------------|----------|
| Overall application performance | 7.95 | 0.89 | 0.9 |
| Screen | 8.1 | 0.84 | 0.91 |
| Terminology and information | 7.88 | 0.99 | 0.97 |
| Learning | 8.09 | 1.06 | 0.99 |
| General impressions | 7.93 | 0.91 | 0.92 |
| Average | 7.99 | 0.93 | 0.93 |

and variables associated with the new patient and the operation performed; Identification and follow-up of signs and complications after lithotripsy; Familiarity with diets and tracking water consumption; Various reminders to prevent stone recurrence.

Since usability and its factors are a well-known factor in determining the success and acceptance of software, applications and IT technologies, this issue has received much attention and various studies have been conducted to develop criteria for evaluating the usability of mobile health programs. In a systematic review study, Zapata *et al* (33) divided usability into attractiveness, learning, performance, and comprehensibility according to the International Organization for Standardization (ISO) 9126-1 quality model. In the present study, users rated the attractiveness (screen) of 8.1, the ability to learn of 8.09, the efficiency of 7.95, the comprehensibility of 7.88 and evaluated it at a good level.

Brown *et al* developed the Information Technology Usability Evaluation Model (Health-ITUEM) as a comprehensive usability assessment framework (34). Health-ITUEM criteria included error prevention, completeness, recall, information needs, adjustability, learning capability, performance speed, competency, and other outcomes. The average opinions of the users of the self-care application designed in this study were 7.35 for error prevention, 7.95 for completeness, 7.8 for recall, 7.88 for information needs, 7.1 for adjustment, 8.09 for learning, 7.05 for performance, 7.93 for competency and were evaluated at a good level.

In the study of Yasini *et al*, “usability” included ease of use, readability, information needs, performance,

flexibility, user satisfaction, completeness, and good feeling of the user after using the program (35). In the present study the following criteria evaluated: 8.4 for ease of use, 8.05 for readability, 7.88 for information needs, 8.1 for flexibility, 7.9 for user satisfaction, 7.93 for completeness and 8.1 for good user feeling after use.

In various studies, the QUIS questionnaire has been used as a suitable and standard tool to assess the usability of software, applications and websites that measure user satisfaction in various areas. QUIS was utilized to evaluate the smartphone application for pregnant women in the embryonic cord blood bank (36), to evaluate the self-care application for patients with heart failure (25) and to evaluate the tele-dermatology software (37). In the present study, the QUIS questionnaire was used to evaluate the usability of the designed software.

According to the results of studies conducted by Valente (26), the proposed application has adopted an appropriate approach in increasing the amount of water consumption and patient self-monitoring with the possibility of recording water consumption, recording urine volume and pH, sending reminders throughout the day and reporting in the form of appropriate graphic design.

According to the researches (38-40), in the present study, in order to improve the diet to prevent recurrence of kidney stones and increase patients’ knowledge in the field of proper nutrition, nutritional recommendations appropriate to the type of urinary stones have been presented to the patients.

A study conducted by Mohammed RF *et al* to investigate the “Impact of Health Education Program

for Elderly Patients Undergoing Extracorporeal Shock waves Lithotripsy on Clearance of Urolithiasis” showed that the training program had a significant effect on patients’ knowledge and Stone removal after ESWL (41). The educational content of the self-care application for patients with kidney stones comprises familiarity with kidney stone disease, familiarity with ESWL, Percutaneous Nephrolithotomy (PCNL) and Transurethral Lithotomy (TUL) lithotripsy methods, as well as familiarity with appropriate exercises after lithotripsy. The proposed application facilitates patients’ access to the necessary training and knowledge in the field of kidney stone disease without time and space restrictions.

Conclusion

Although, most of the caring of kidney stones is done by health care providers and patients themselves, the use of mHealth technology is recommended as an effective tool to facilitate patients’ access to their health information and to improve their self-management skills.

The specific nature of kidney stone disease and the possibility of recurrence during the years after kidney stone treatment requires special attention to design and create an appropriate self-care application to provide training, lifestyle modification, counseling and increasing patient awareness. To achieve this goal, a web-based self-care application for patients with kidney stones undergoing extracorporeal lithotripsy was designed and provided to the medical staff and the patients referred to Sabalan Hospital in Ardabil, Iran. In the proposed application, an attempt has been made to pay attention to different dimensions of kidney stone disease. In addition to attractive design, ease of use and access to users, the followings were the advantages of the designed application: providing training in familiarity with kidney stones and its treatment methods, recording daily water consumption, sending reminder messages to the patients, recommendations, nutritional measures appropriate to the type of kidney stone, communication with the treating physician, monitoring the condition of patients after lithotripsy, recording PH and urine volume and medications.

The results of this study demonstrated that the designed web-based self-care application has been able to satisfy the users. From the users’ viewpoint, the usability of the self-care program was evaluated at a good level with an average score of 7.9 out of a total of nine points. The usability of the self-care application in various areas of overall functionality, display, terminology, learning capability and overall application capability was satisfactory to the users.

In this study, we encountered limitations, some of them are: in the needs assessment stage due to synchronization with the conditions of the corona virus; reducing the patient visits and reducing the number of samples in the evaluation phase due to corona; the limited possibility of comparing research findings with reliable sources due to the lack of studies in the field of evaluation of self-care applications for patients with kidney stones.

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The study did not receive any funding.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

Data are available from the corresponding author on reasonable request.

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Conflict of Interest

Authors declare no conflict of interest.

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