

A Mobile Health Application to Enhance Self-Management Skills of Patients with Shoulder Impingement Syndrome During Rehabilitation

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Abstract

Especially in chronic diseases, such as shoulder impingement syndrome (SIS), good self-management is important for patients to take personal responsibility for their treatment and make informed decisions in rehabilitation processes. Mobile apps integrating game design elements have great potential to increase patients' self-management skills. A total of 21 functionalities for a self-management app were derived from semi-structured interviews with six patients and three therapists. Thereby, 'welcome messages', a 'personalized home-screen', and 'training plans' are rated as particularly useful. Ten of these functionalities could be implemented in a first prototype of 'SISco: your shoulder impingement syndrome companion'. SISco provides possibilities for creating and executing training programs, learning about SIS, checking daily challenges, and making diary entries. Thereby, SISco motivates patients via progress bars, collecting XP, unlocking content and 'Dr. SISco' the virtual therapist. Future work includes the implementation of further functionalities and the evaluation of SISco for usability and user acceptance.

Keywords:

Self-Management; Shoulder Impingement Syndrome; Mobile Applications

Introduction

As most flexible joint, the shoulder is affected particularly frequently by symptoms of overuse [1]. Quite often, this overuse is manifested as impingement syndrome, a soft tissue incarceration within the shoulder joint [2]. Shoulder impingement syndrome (SIS) is the second most common cause of chronic shoulder pain [3]. SIS causes severe pain even during everyday movements, such as lying down, lifting the arm, or rotating it [4]. Patients also show functional impairments of joint mobility. Due to its long healing period, SIS is considered as a chronic disease, typically first appearing between the ages of 30 and 40 [1,5].

Depending on the duration of symptoms, pain intensity, apparent dysfunction, and the extent of structural damage, SIS can be treated conservatively or surgically [4]. The conservative treatment is composed of different phases. In the acute phase, the primary goal is to reduce pain by consistent rest and, if necessary, the use of pain-relieving medications [4]. In the second phase the passive and finally active mobility is addressed. Gaining muscles and increasing coordination are the final steps. Thereby, suitable therapeutic procedures are selected on an individual basis according to the patient's clinical profile. Regular training outside physiotherapy facilities may support the treatment [4].

Active participation of patients in the care process is necessary for a sustainable rehabilitation success [6]. Enhancing the self-management skills of patients is a possibility to achieve this. Good self-management is characterized, above all, by the assumption of personal responsibility and the ability of a patient to make informed decisions about one's own lifestyle [6].

Since the smartphone is now widely used and always available in everyday life, the self-management of impingement patients could be enhanced with a mobile health application (mHealth App). Thereby, game design elements can be used to further motivate patients in managing themselves [7]. Game components such as points, level, and unlocking content, may help to use the app's functions on a regular base [8]. Additionally, it offers an interactive way to inform and support patients. However, to date, no mHealth App seems to exist that provides patients holistic support in self-management during the long-term rehabilitation process.

This paper presents the mHealth App 'SISco: your shoulder impingement syndrome companion', which aims to enhance self-management skills of patients with SIS during the entire rehabilitation process.

Methods

The analysis and specification of functional requirements for SISco is composed of three parts. First of all, a qualitative study was conducted to analyze the status quo of self-management in patients with SIS. In a second step, a supplementary app search was conducted to elaborate additional requirements, respectively potentially relevant functionalities. Afterwards, the functional requirements determined were validated. Non-functional requirements were defined using latest quality standards and legal regulations. Finally, initial mockups were created as a basis for the implementation of SISco.

Qualitative study

To determine the status quo of self-management in patients with SIS a qualitative study using semi-structured guided interviews (*survey research*) with patients and therapists were conducted [9].

Patient survey

The aim of surveying patients was to assess their satisfaction with their own self-management skills as well as the current extent of self-management. For this purpose, only patients with SIS (M75.4) or another shoulder syndrome (M75.-) with comparable procedures and duration of rehabilitation should be included. Thereby, patients with acute disease as well as

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recovered patients after conservative or surgical treatment were included. Patients without a confirmed SIS diagnosis by a physician were excluded. Patients aged under 18 years or incapable of giving consent were also excluded.

Interview participants were recruited by contacting various rehabilitation centers and physical therapy practices in Braunschweig, Germany, by telephone or via e-mail. Given the limitations present at the time of study design due to the COVID-19 pandemic and the associated poor patient contact opportunities, a sample size of at least three patients was targeted.

Based on a self-developed interview guide with defined topic and question blocks, the telephone interviews were conducted in a structured manner. Mostly open questions were asked on the following topics: (1) Characteristics of the underlying disease and treatment, (2) current extend to which self-management is practiced, (3) satisfaction with the status quo of self-management, (4) informedness and motivation of patients, (5) potentials for improvement, and (6) requests for an self-management app. In addition, Likert-scales were used to assess opinions and feelings. A clustering of answers around the neutral middle was avoided by using a four-point scale.

Therapist survey

A supplementary survey of therapists was aimed at considering their professional experience during the development of SISco. For this purpose, therapists with experience in the treatment of musculoskeletal disorders of the shoulder should be interviewed by telephone, e.g., physical and occupational therapists, chiropractors, or osteopaths. Thereby, it was not important whether a therapist is currently still actively practicing. Even non-active therapists can contribute professional experiences from the past. Therapists with less than three years of work experience were excluded.

Recruitment was equivalent to patients. Likewise, the aim was to interview at least three physical therapists.

A separate interview guide, mainly with open questions, was created for therapists. This includes questions on the following topics: (1) Profession and work experience, (2) contribution of therapists to a patients self-management skills, (3) patient participation, (4) potentials for improvement, and (5) requests for an self-management app.

Data analysis

The interview transcripts were analyzed by qualitatively oriented category-guided text analysis. The individual answers of interviewees were classified into categories, i.e. coded. To ensure objectivity, intercoder reliability was checked by categorizing parts of the material to be coded by a second coder. Deviations were discussed in a coders' conference between the two coders. Responses to Likert-questions were counted and tabuled.

App search

A brief app search were conducted to identify further potential requirements in existing mHealth Apps. The Apple App Store was searched in German using the keywords impingement, self-management, chronic pain, rehabilitation shoulder, shoulder pain, and medication manager. Only apps of the category health, which are available free of charge were considered. To ensure a minimum level of quality, only apps with an user rating of at least four stars were included.

Specification and validation of functional requirements

Concrete app functions were derived from the core aspects of the different interview topics and segmented into individual functional requirements. The structure of a function consists of a unique identification, a justification, a prioritization, and a source citation, from where it was derived [10]. Prioritization was done in a user-oriented manner according to the MoS-CoW method [11]. To validate the specified requirements, a feedback round with all interview participants took place in the form of an online survey. Participants were asked to rate the identified app features according to their subjective usefulness as a function of a self-management app for shoulder conditions. The rating scale for the app function included four response options from 'not helpful at all' to 'very helpful'. Any function with a mean rating of 2.5 was considered as sufficiently helpful.

Specification of non-functional Requirements

Non-functional requirements were determined on the basis of the international ISO/IEC25010:2011 standard for software quality [12]. Furthermore, requirements for data protection, especially with regard to the processing and use of personal data, were defined. Here the European General Data Protection Regulation (GDPR) and the German Federal Data Protection Act (BDSG) were taken into account.

Implementation

The app was developed for android devices. To run SISco, at least Android version 4.1 is required. Android Studio was used as development environment. Various Android libraries were used to implement the app. The Android Jetpack libraries with the namespace 'androidx' were used predominantly.

The library 'androidx.constraintlayout:constraintlayout:1.1.3' was used to layout the content of SISco. Advantageously, the content can be aligned directly to the layout components. As a result, in contrast to a linear layout, the individual layout elements are not aligned with the screen size.

For the implementation of the navigation drawer the 'androidx.navigation:-fragment:2.3.0' library was used. This version allows to change the name of app bars depending on the current content. Furthermore, individual fragments can be used to switch between different areas of the app without opening a new activity.

Results

A total of six patients aged 49 to 61 years were interviewed over a three-week period (Table 1). An interview took 34 minutes on average. Three of these patients have an impingement diagnosis. Of the other patients, one each suffers from rotator cuff injury, supraspinatus tendon rupture, and frozen shoulder. Three of the six patients underwent surgery. Physiotherapy has already been completed for one patient.

Table 1- Patient demographics

ID	Age	Gender	Date of diagnosis	Date of surgery
P1	55	Female	2018	2020
P2	49	Male	March, 2020	-
P3	53	Female	2018	2020
P4	61	Male	2014	2014
P5	55	Female	January, 2020	-
P6	53	Female	January, 2020	-

The three therapists interviewed are or were working as physiotherapists and have three, ten and eleven years of professional experience. Among other things, they are trained in electro muscle stimulation (EMS), taping, manual therapy, sports physiotherapy, naturopathy, and orthopedics.

Functional requirements

A total of 21 app functionalities were derived from the analyses (Table 2), resulting in the specification of 63 functional requirements for their implementation.

Table 2- Specified app functionalities

ID	Name	Implementation
Basic functions		
FA1	Legal notice	✗
FA2	User Account	✓
FA3	Profile	✓
Training and relaxation		
FA4	Training plan	✓
FA5	Relaxation program	✓
FA6	Daily challenge	✓
Reminder		
FA7	Training reminder	✗
FA8	Medication reminder	✗
FA9	Reminder for medication used	✗
Information		
FA10	Blogs	✗
FA11	Personal adviser	✓
Comfort		
FA12	Welcome messages	✓
FA13	Personalized home-screen	✓
FA14	Appointment wizard	✗
FA15	Connection to fitness tracker	✗
Communication		
FA16	Community (social media)	✗
FA17	Connection to therapists	✗
Motivation		
FA18	Badges and points	✓
FA19	Journal	✓
FA20	Progression history	✓
FA21	Self-management test	✓

All patients and therapists participated in the short survey for validation of app functionalities. The completion time was between 4 and 14 minutes. Of the 18 app functions evaluated, 17 were rated with a mean of at least 2.56 points (max = 4 points). Only the functionality 'badges and points' (FA18) was rated as not sufficiently helpful. The participants perceived 'welcome messages' (FA12), a 'personalized home-screen' (FA13) and the 'training plan' (FA4) to be particularly useful.

Non-functional requirements

Using the ISO/IEC 25010:2011 standard, requirements for effectiveness, efficiency, satisfaction, risk-free, context coverage, functional usability, performance, compatibility, usability, reliability, maintainability, transferability, and security could be defined. Thereby, special attention is paid to effectiveness, risk-free, usability, and security. Since impingement patients tend to be older and thus less experienced in using apps in general, it is especially important that they can operate the app without assistance and without triggering error messages. The app is not permitted to expose the user to any additional health risks. The patient's health data must be particularly protected by measures such as encryption and authentication.

SISco: your shoulder impingement syndrome companion

20 of the 63 functional requirements could be implemented in a first prototype (Table 2), which is currently still under development. The mHeal App SISco offers patients with SIS individual support in the rehabilitation process. To this end, the app provides patients with extensive information on SIS rehabilitation, individualized training plans, and assessments to reflect on their individual progress. SISco always addresses the patient directly to create proximity, e.g., through personalized messages and a virtual therapists who talks to the patient. Overall, patients become more involved in their own treatment.

User Account

To use the app, patients have to register and create an user account first. For verification, a login via the email address and a password set by patients is used. The password must consist of at least eight characters, one upper case letter, one lower case letter, and one number. After registration, users will receive a confirmation link to their e-mail address for verification. Login to the app is now possible at any time using the email address and password.

The creation of a user account and verification of users is done via Android firebase. Firebase is a mobile platform provided by Google, which manage user accounts and the corresponding data [13]. With the firebase-auth-service users can be easily verified and authorized.

Home-screen

After login to the app, patients receive a personalized welcome message at the top of the home-screen, e.g., 'Hello Steve, nice to see you today. You have trained the last time on 17.05.'. In addition, the last opening of the app is displayed, as well as a daily motivational quote (Figure 1). In the area below, patients can view their progress. For visualization, experience points (XP) are used. These can be collected in the areas 'quiz', 'training', 'journal' and 'daily tasks'. The XP displayed are summed up from individual tasks in the app and summarized here as the current status. With the help of different levels (1-3), patients are able to realize their growth potential. This way, the motivation to put training and documentation into daily practice can increase.

On the home-screen, patients also see three daily tasks. These are automatically selected depending on the patient's progress and the last day's tasks. For example, the tasks in the first app usage serve to learn how to use SISco (Figure 1). If patients tap on the daily task, the execution will be confirmed. The associated progress bar, which represents the XP earned, immediately grows.

The menu is also accessible via the home-screen, and thus all other sections of the app: (1) information, (2) training, (3) journal.

Information-screen

The information-screen offers background knowledge about SIS and serves patients as personal adviser. The information section is categorized in the subsections 'clinical picture', 'therapy option', and 'legal situation'. Information is provided via a combination of textual descriptions and images. Clarity is achieved by keeping descriptions as short and concise as possible and dividing the topics mentioned above into different chapters. Similar to a book, it is possible to turn the page

in a chapter by swiping. Dots at the top of the screen indicate

The training overview is organized by difficulty. There are

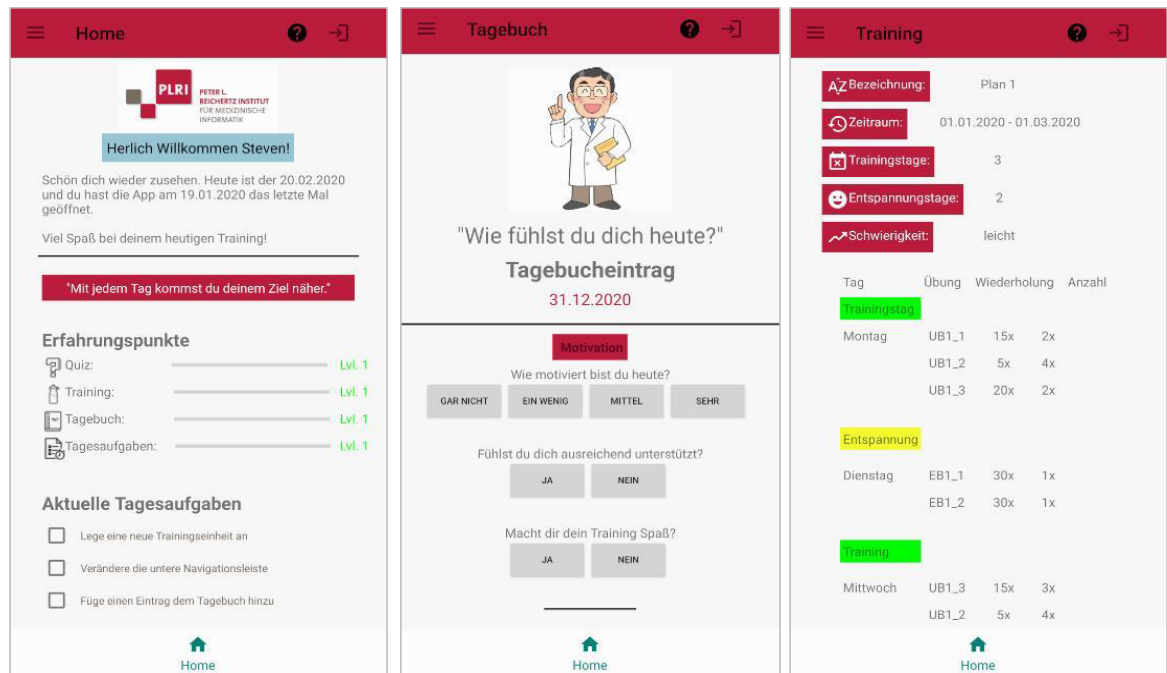


Figure 1- Screenshots of the app SISco in German language

which 'page' a patient is currently on.

Each section ends with a short quiz to strengthen the acquired knowledge. Successfully completing a quiz can also unlock new content, i.e. new chapters (*cascading information*). This allows patients to build up knowledge step by step and thus avoid being overwhelmed by a flood of information [14]. Furthermore, patients will be motivated to edit sections and unlock further information.

By completing a quiz, patients also receive XP, according to the correct questions answered. XP can be collected only once for each correctly answered question. The questions are asked by the virtual therapist 'Dr. Sisco'. A virtual partner, he supports patients in the learning process. Thus, the app gets a social component without actually integrating social interaction.

Training-screen

The training-screen offers information on training plans, relaxation programs, and single exercises. Therefore, it contains functionalities to show all trainings plans (*training overview*), all exercises implemented (*exercise overview*) and the actual training plan (*training plan*). In addition to predefined training plans, patients have the possibility to create their own plans. To propose suitable exercises for a patient, patients must first enter a set of basic information, such as the targeted difficulty level, the desired training frequency, and the duration of a training session. Selecting appropriate exercises is possible for every other day to avoid overtraining. For each exercise, patients can also indicate whether it causes them pain or not. If an exercise causes pain, the plan will be automatically changed and the affected exercise removed. This not only allows individualization of trainings, but also gives patients more freedom and flexibility. As a result of this self-determined behavior, an increase in motivation for regular training is conceivable.

four levels of training difficulties: easy, medium, heavy, extreme. The number of shoulder exercises and relaxation exercises is displayed per training period. Additionally, patients can click on a button to get more information about a single training, for example, how the exercises are assigned to each day of the week. The section 'exercise overview' is structured similarly.

Patients can view their current training plan via the 'training plan' section (Figure 1). For each training plan you can see the period over which it is to be performed, how many training days and how many relaxation days it consists of, and the level of difficulty. For each day of the week it is also indicated which exercises are to be performed with which number of repetitions in how many training sets.

Journal

In the journal, patients can create and retrieve diary entries. Predefined questions document the current status on motivation, training, and pain (Figure 1). Dr. Sisco is responsible for the query. These self-assessments provide an overview of the patient's daily condition. Detecting pain or lack of motivation during training is another benefit. This may help to create an individually and more efficient training, based on the mental and physical health condition of patients.

Discussion

Using semi-structured interviews with patients and therapists and a minor app search in the Apple App Store, it was possible to specify 63 functional requirements for a self-management app for patients with SIS. Based on a qualitative content analysis of the interview transcripts, 21 relevant app functionalities were accordingly identified and finally prioritized via online interviews with patients and therapists. Ten of

these functionalities were finally implemented prototypically in the SISco app.

The patient interviews provide good insight into how patients are currently coping with their disease, as well as the challenges they have faced. Here, not only patients with SIS were interviewed. Related shoulder diseases were also included. Given the similarity in therapy, it was assumed that these interviewees would also be able to report experiences that also apply to SIS. Furthermore, without expanding the inclusion criteria to other chronic shoulder diseases, it would not have been possible to survey a sufficiently large set of interviewees; only three instead of six. The low recruitment number can be explained, among other things, by the COVID-19 pandemic and the associated poorer accessibility of patients.

The interview transcripts were analyzed by means of category-guided text analysis by one coder. It is questionable whether coding by two coders would have led to different results and thus to different functional requirements, i.e. app functionalities. However, since at least an intercoder reliability check took place for two randomly selected interviews, it is assumed that the quality of coding is sufficient.

The app search was performed exclusively in the Apple App Store with a small set of search terms. An additional search within the Google Play Store was omitted. The restriction to minimum user ratings of four stars limits the amount of results even more. Overall, only five relevant apps could be identified and analyzed. However, since the app search was only a minor part of the analyses and served only to get further ideas about popular and useful functionalities in the context of self-management, this procedure still seems sufficient.

Almost all app functions were rated as sufficiently helpful in the online survey. Surprisingly, participants rated badges and points as not helpful. Despite this, achievements and points, as XP and level ups, were integrated in SISco. The assumption is that the corresponding functionality and the effects on the use of the app could not be adequately represented in the online questionnaire.

In total, 10 functionalities could be implemented in SISco. This represents less than half of all functions identified in the analyses conducted. In particular, little attention has been paid to non-functional requirements, except for data protection and data security. Furthermore, due to its user-oriented focus, the app does not represent all relevant technical aspects. The further development of SISco should therefore not only focus on the implementation of further functionalities, e.g., reminders and a communication channel to the treating therapist, but also on legal, performance, security, and technical requirements.

So far, SISco is not downloadable from the Google Play Store. This is planned as soon as further functionalities, especially the basic functionalities, have been adequately implemented and first tests with users have taken place. However, support for self-management is already possible with the current app version.

Conclusions

Active participation of patients in the care process is necessary for a sustainable rehabilitation success, especially for patients with chronic diseases, like SIS. Enhancing the self-management skills of patients play an important role in disease management. With SISco a mHealth App is presented, which provides patients holistic support in self-management during rehabilitation. For this purpose, SISco offers function-

alities for creating and executing training and relaxation programs, learning about the disease and treatment, checking daily challenges, and making diary entries (*self-assessment*). Thereby, SISco motivates patients for long-term use of the app via providing progress bars, collecting XP, unlocking content and Dr. Sisco the virtual therapist. To deploy the app in practice, it is necessary to expand the concept for data protection and data security and to implement further essential functionalities, such as reminder and communication opportunities. Moreover, usability and user acceptance are to be evaluated in a pilot study.

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