Prototype Application for the Treatment of Achilles Tendinopathy

30th June 2021

Lucy G. Knöps | MSc Technical Medicine | Department of Orthopaedics and Sports Medicine, Erasmus MC
Valentijn Visch | Associate Professor Persuasive Game Design | Faculty of Industrial Engineering, TU Delft
Jos Kraal | Assistant Professor Behavioral Change | Faculty of Industrial Engineering, TU Delft
Niko Vegt | Post-doctoral Researcher Healthy Storytelling | Faculty of Industrial Engineering, TU Delft
Robert-Jan de Vos | Associate Professor and Sports Medicine Physician | Department of Orthopaedics and Sports Medicine, Erasmus MC

Abstract

Introduction

Adequate treatment of Achilles tendinopathy (AT) consists of patient education, load management advice and calf muscle strengthening exercises. mHealth comprises the delivery of healthcare by mobile devices and is expected to be beneficial in the treatment of AT by including motivational features in the application, as well as providing features for adequate self-management. Therefore, the aim of this project is to develop a prototype application for the combined treatment of AT.

Methods

To develop a user-centered prototype application, multiple steps were taken to develop the final prototype of this project. Exploratory literature and user research was done, after which patient scenarios were written and interviews with patients were conducted. This resulted in a set of requirements for the prototype application, which were processed in a patient journey, user flow diagram and flowchart. Wireframes were sketched and an interactive prototype was developed in Axure (Axure Software Solutions, Inc., San Diego, California). The interactive prototype was evaluated by patients and healthcare providers using structured interviews. Based on the results, a final interactive prototype was built.

Results

Literature research and patient interviews (n=3) resulted in a set of requirements. The patient journey, user flow diagram and flowchart, were useful to prioritize the requirements and to define the structure of the application. Wireframes of the application screens were sketched, which was helpful for the development of the interactive prototype in Axure. Interviews with patients (n=2) and healthcare providers (n=3), in which the interactive prototype was assessed, highlighted the positive expectations about the application, but highlighted also required improvements. With the given feedback, a final interactive prototype was developed.

Conclusion

The prototype application developed in this project is an important step towards a mHealth application for the delivery of the combined treatment of AT. In future research, it is needed to define decision trees with cut-off points to decide which personal advices are given at what moment and based on what data, to decide when progression to the next phase of exercise therapy is indicated, and to decide which information is provided to which patients.

Keywords

Tendon, tendinopathy, patient self-management, therapy adherence, mHealth application, user-centered design.

Index

1. Introduction

1.1 Project Context

This project is performed as part of a Technical Medicine internship at the Department of Orthopaedics and Sports Medicine at the Erasmus MC University Medical Centre in Rotterdam, with support of the Department of Industrial Design Engineering, TU Delft.

1.2 Clinical Context

1.2.1 Introduction to Achilles Tendinopathy

Achilles tendinopathy (AT) is a clinical condition with localised Achilles tendon pain in association with mechanical load [1]. There are two subtypes of AT; midportion AT, with symptoms 2-7 cm from the insertion at the calcaneus, and insertional AT with symptoms within 2 cm from the insertion at the calcaneus [2]. In insertional AT, deep dorsiflexion angles are provocative, because of the high traction on the Achilles tendon and the high pressure from the tendon on the calcaneus. An incidence of almost 2 per 1,000 registered patients in Dutch general practice has been reported and about 52% of runners experience AT in their lifetime [3,4]. However, AT is also observed in inactive individuals in approximately one third of the cases [5]. The incidence has increased in the past decade, which is expected to be caused by the increasing amount of people performing sports activities [1,6]. Risk factors include black race, higher body mass index, prior tendinopathy or fracture, lower plantar flexion strength, greater weekly volume of running, more years of running, use of spiked or shock absorbing shoes, training in cold weather, the use of oral contraceptives, the use of hormone replacement therapy, reduced or excessive ankle dorsiflexion range of motion and the use of fluoroquinolonen-antibiotics [2,6]. The pain and impaired load-bearing capacity associated with AT showed to have a large impact on patients' quality of life (QoL) and work productivity. Moreover, patients with AT require substantial healthcare with associated costs. Total mean estimated annual costs were reported to be €840 per patient suffering from AT [1].

1.2.2 Treatment and Prognosis of Achilles Tendinopathy

According to the new Dutch multidisciplinary guideline 'Achilles Tendinopathy', the cornerstone of treatment consists of patient education, load management advice and calf muscle strengthening exercises [2]. Patient education consists of three elements: explanation about AT, explanation about the prognosis and pain education. The most important aspect of load management advice is temporarily replacing pain-provoking (sports)activities with non-provoking (sports)activities [2]. Thereby, the (sports)load can gradually be increased, based on monitoring the pain experienced with (sports)load. Exercise therapy consists of four (midportion AT) or five (insertional AT) phases with exercises gradually increasing in load [2]. For insertional AT, first, exercises are done avoiding deep dorsiflexion angles of the ankle. If these exercises are well tolerated, exercises from a step are indicated, to train the tendon in deep dorsiflexion angles. The exercises have to be performed on a daily basis and after 8-12 weeks, improvement is normally expected [7].

The prognosis of AT is highly variable and treatment outcomes are difficult to predict. Two-thirds of the patients with AT feel completely recovered 1 year after initiating treatment. Of the athletes treated for their AT, 55-90% have returned to their sport after 1 year. Which portion of athletes return to their sports completely free of symptoms, is unknown [2]. Most patients do no longer experience pain after 10 years, but a small subgroup of approximately 20-30% experiences recurrent symptoms despite multiple treatments [2].

1.2.3 The Importance of Self-Management in the Treatment of Achilles Tendinopathy

Self-management is an important aspect of the combined treatment strategy for AT, requiring patient education, the collaborative use of behavioural change techniques to foster lifestyle change and the adoption of health-promoting behaviours [8]. This will probably lead to patients integrating the treatment advice into their lives. Supporting patients with self-management of AT, including extensive patient education, load management advice and exercise therapy, is time consuming for healthcare providers. Moreover, the combined treatment is currently provided by consultations, leaflets, information on websites or via different (para)medical healthcare providers, which leads to

heterogeneity of content. This highly varying content of treatment and time intensive support of patients with AT, state the need for a mHealth application in the treatment of AT.

1.3 eHealth and mHealth Applications

eHealth and mHealth are rapidly upcoming, and showed their benefits in patients' self-management. eHealth comprises the use of internet technology to support and/or improve health and healthcare. The technology used to improve healthcare with eHealth include electronic health records, patient administration systems, lab systems and other records that cannot be stored within mobile health applications. In contrast, mHealth is the delivery of healthcare by mobile devices, as smartphones, pedometers or GPS. Patients are able to log, store, and monitor their health records on their personal mobile devices. A recent study investigated the needs, experiences, and views of patients with rheumatic and musculoskeletal diseases on mHealth applications [9]. The authors concluded that patients considered using an application, if the application could help them to self-manage their rheumatic and musculoskeletal disease condition. Moreover, the application had to be tailored to their needs and co-developed with health professionals. mHealth delivers treatment in a consistent way and has proven to enhance patient-centered care and improve health literacy in patients, which promotes self-care [10]. Another important potential benefit of mHealth is the opportunity to include strategies that improve treatment adherence.

Therefore, a mHealth application for the delivery of the combined treatment of AT will likely be valuable in improving clinical outcomes, by presenting motivational features in the application, as well as providing features for adequate self-management.

1.4 Objectives

The overall aim of this project is to develop a prototype application for the delivery of the combined treatment of AT, including patient education, load management advice and calf muscle strengthening exercises. The desirability and usability of the prototype will be assessed by a small patient population and the relevance and content of the prototype will be evaluated by healthcare providers.

2. Process

To develop a user-centered prototype of the application, which is based on the new Dutch multidisciplinary guideline 'Achilles Tendinopathy', multiple steps were taken to develop the final prototype of this project.

2.1 Literature Research and User Research

Exploratory literature research was done on AT, self-management, mHealth and healthcare applications, as well as exploratory research on the development of applications, including user-centered design, the importance of user scenarios and the steps to be taken to develop a healthcare application. Subsequently, user research was conducted. Future users of the application include two groups. Patients suffering from AT will be the primary future users of the application. Healthcare providers involved in the treatment of AT are important in advising the application to their patients. They may play a role in determining the content of the application and may use the registered data in the treatment process of their patients.

Information about patients with AT was obtained by joining consultations of patients (n=6) with an experienced sports medicine physician in the Erasmus MC. This patient research helped to gain knowledge about the patient group and to identify patients' needs and pitfalls. The input of one sports medicine physician in the Erasmus MC was used to inventory the most relevant content and features of the application from the perspective of a healthcare provider.

Knowledge about AT, the patient group and the development of health applications, aids in developing an application that is user-centered and includes all relevant aspects of the treatment of AT.

2.2 User Scenario

Extensive knowledge about patients with AT was obtained by user research. This formed the basis of writing user scenarios to deeper understand patients' motivations, needs and barriers. User scenarios are

helpful in understanding the context of how patients would use the application and describe the experience of patients using the application.
To describe realistic scenarios, the following factors were clearly defined, based on the user research:

- Background, describing who our users are;
- Motivations, describing what goals the users want to achieve;
- Tasks, describing what users must do to reach those goals;
- Context of use, describing how the users will encounter the application, including the environment where they will use it and the challenges experienced when using the application.

See Table I, for the definition of these factors.

Table 1 - Description of patient factors

Background	**Motivations**	**Tasks**	**Context of Use**
Patients with midportion or insertional AT	Return to (sports) activities without pain	Perform exercises on a structural basis	The application can be used anywhere to read information, perform exercises and register activities and pain scores
Patients are usually active and participating in sports	Return to (sports) activities as soon as possible	Monitor pain scores related to exercises, activities and their average pain scores	The application will be used mostly at home
Patients are usually runners	Self-management as treatment strategy	Temporarily stop pain provoking (sports) activities and replace them with non-provoking (sports) activities	The application will be used on a daily basis
Patients are adult	Feel well educated about AT and the treatment options	Stay active and keep up the physical condition	The application can be used offline
Patients usually have a basic understanding of (sports)activities and healthy lifestyle	Perform exercises correctly	Gradually increase normal (sports) activities based on pain scores and phase of exercise therapy	
	Keep track of the progress		
	Prevent recurrence of AT		

Subsequently, three user scenarios were written, describing the use of the application by three different patients with AT. We then decided to focus on one user scenario, describing the most reflective patient for the AT patient population (Appendix I). We recorded the most important needs and experiences of the typical AT patients. This user scenario was further developed and the use of the application was integrated in the story. Moreover, a visual presentation was created in Powerpoint using Scenes illustrations, to visually support the user scenario [11,12]. The Powerpoint presentation is displayed in Appendix II.

2.3 Patient Interviews

The next step was to interview patients to learn what their experiences are with the current treatment of AT and inventory their thoughts and needs about the application. This would contribute to a user-centered design of the application and will help defining the content, structure and design of the application.
A number of patients (n=5) was assembled at the tendon clinic in the Erasmus MC, three patients (2 men, 1 woman) agreed to participate for the user interviews. The included patients were asked to sign an informed consent form, before the interview.
During the interview, an introduction to the objective of the project was given. Subsequently, the basic features and content of the application were described. Also, the user scenario was narrated to the patient with visual support by the Powerpoint presentation. Afterwards, patients were asked questions comprising the following topics: knowledge about AT, current treatment of AT and the use of the application in the treatment of AT. To support the conversation with patients and to make sure all important information was assembled, an interview guide was conducted. Appendix III includes the interview guide.

2.3.1 Results Patient Interviews

Objectives of the Treatment

Patients aimed to experience less pain in their daily activities, be completely pain free or to be able to participate in sports, and perform activities without limitations.

Understanding of AT by Patients

The pathology of the Achilles injury was understood globally. The treatment of AT was correctly understood. All patients mentioned the most important aspects of the treatment, as exercise therapy focused on strengthening of the calf muscles and slowly increasing the (sports) activities, based on their experienced pain levels. One patient thought the exercises to be stretching exercises to keep the tendon warm and flexible. Later in his treatment process, he understood the aim of the exercises was to increase the loadbearing capacity of the calf muscles and Achilles tendons.

Treatment Experiences

All patients thought the treatment process to be slow. They mentioned the difficulties of the prolonged duration of the healing process and the aim to return to their daily activities as fast as possible. Nevertheless, the guidance in their treatment by the sports medicine physician, and advices and information they received, were experienced as suitable and beneficial. All patients felt like they are moving towards complete recovery because of the treatment and they expect more improvements in their condition. In terms of therapy adherence, all patients claimed to never skip their exercises, but occasionally perform the exercise therapy faster or shorter than recommended. Besides, the distribution of exercise therapy over the week was sometimes deviating from what was recommended by the exercise schedule.

Expectations of the Application

Two out of three patients were positive about using an application in the treatment of AT. One patient responded that he does not see the benefit of using an application for the treatment and he is satisfied with the guidance of the physiotherapist. However, at the end of the interview, this patient was asked if he would use the application if it existed and his answer was positive.

The patients expected the application to be advantageous in multiple aspects. First, reminders for exercise therapy were expected to be an important feature, to keep motivated and to not forget the exercises. Second, they mentioned an exercise therapy guide, which should lead the patient through the daily exercise program, including an instruction video and a short explanation per exercise. Instruction videos were thought to be of value to make sure the exercises are correctly performed. Moreover, this exercise therapy guide was thought to be useful when it has the feature to automatically progress to the next phase of exercise therapy, when this is indicated. Third, patients thought the progression overviews provided by the application were of high value, because this would motivate them to keep going. Another feature the patients expected to be beneficial, was the ability to track workouts or physical activities and to get advices for the next training based on the registered activities. Moreover, the inclusion of running schedules was thought to be of value. Last, one patient expected to be better motivated, when the application would send the completed exercises and workouts to the sports medicine physician or physiotherapist. He expected his performance level and therapy adherence to be higher when the health provider has continuous insight in his treatment results.

All patients would prefer to use the application at home, but would be aware of the possibility to use the application somewhere else, for example during the physiotherapy visits. They would want to receive notifications that are reminding them of doing the exercises or registering their pain scores and workouts, or notifications with advices regarding their load management. Patients stated they only would want to receive relevant notifications with actions they directly have to perform. The expected moments of use of the application would be around the performance of exercise therapy and workouts or at the moment pain scores have to be registered.

For the understanding of the Achilles tendon injury and suitable therapy, patients do not expect the application to be of significant value. They believe it is the healthcare providers' job to explain the most important factors and think that leads to a sufficient understanding.

Top 3 Features
Patients were asked to construct a top 3 of features they thought to be the most relevant features in the application. Table II includes the answers.

Table 2 - Top 3 features in the application, according to the interviewed patients

	Patient 1	**Patient 2**	**Patient 3**
1	Reminders for exercise therapy	Advices for building up (sports) activities	Communication possibilities: results are directly sent to healthcare provider
2	Advices for building up (sports) activities	Registering (sports) activities with pain scores	Advices for building up (sports) activities
3	Registering pain scores	Clear instructions of exercises	Registering pain scores

2.3.2 Conclusion Patient Interviews
The interviews with patients resulted in an improved understanding of the patients' wishes and expectations about the application. Patients mainly highlighted the need for support during the exercise therapy; they suggested a daily exercise therapy guide which walks them through the daily exercise program and reminder notifications for exercise therapy at a set time. Thereby, they pointed out the difficulty of deciding when to progress to the following phase of exercise therapy. Moreover, patients mentioned their struggle with staying motivated in the long treatment process. They suggested motivational features, such as results being forwarded to their attending healthcare provider, features to track progression in average daily pain scores, exercises, (sports)activities, exercises and steps per day, and reminder notifications for exercise therapy and data registration. Last, patients liked to have support in the build-up of their (sports)activities.
The assessed patients did not think extensive education features would be valuable in the application, but this may be due to the fact that the assessed patients already received extensive explanation about AT.

2.4 Requirements for the Application
Based on the results of the patient interviews and the input of a sports medicine physician, a set of requirements for the prototype application was selected (Table 3).

Table 3 - Set of Requirements for the Application

General Requirements	**Registration and Tracking of Data**	**Progression Overviews**
Differentiation between midportion and insertional AT	Tracking of daily (sports) activities, including distance, duration and pain scores	Progression in pain scores
The opportunity to create a personal profile	Tracking of exercise therapy, including number of completed sets, repetitions and pain scores	Progression in exercise therapy
	Tracking of general daily activity based on number of steps per day	Progression in general daily activities, based on the number of steps per day
	Tracking of average daily pain scores	Progression in (sports) activities

Personal Advices	Daily Exercise Therapy Program	Information Delivery
Load management advices	Reminder notifications to start the exercise therapy Reminder notifications to register pain scores	Information about AT
Workout advices	Reminder notifications to register (sports) activities	Information about exercise therapy
Advices for exercise therapy	Reminder notifications to register number of steps per day	Information about load management
	Exercise therapy guide running through the daily exercise program	Informative videos
	Exercise instruction videos	

2.5 Patient Journey, User Flow Diagram and Flowchart

To prioritize the features we need in our application for the treatment of AT, a patient journey was written. The patient journey describes the process the patient runs through from the first consultation with the healthcare provider to the return to the preferred (sports) activity. It is focused on the use of the application during the treatment process and maps out the patients' specific interactions with the application.

The patient journey highlighted the intensive use of the application during the treatment process of the patient. Because the application was desired to have many features, the patient journey showed the features the patient uses primarily, as the daily exercise therapy program and data registration. In contrast, the use of training schedules to build-up the (sports) activities, was a feature that would be used later in the treatment process. When patients use the application, they want to read information shortly, then perform actions in the application, and when they are further interested, they want to have the opportunity to read more information about an action or topic.

Appendix IV shows the patient journey.

A user flow diagram was built and represented in Figure I. The user flow diagram shows the path patients run through to complete specific tasks in the application, as creating a personal profile, completing the daily exercise program, obtaining information about AT and registering pain scores, steps per day and (sports) activities.

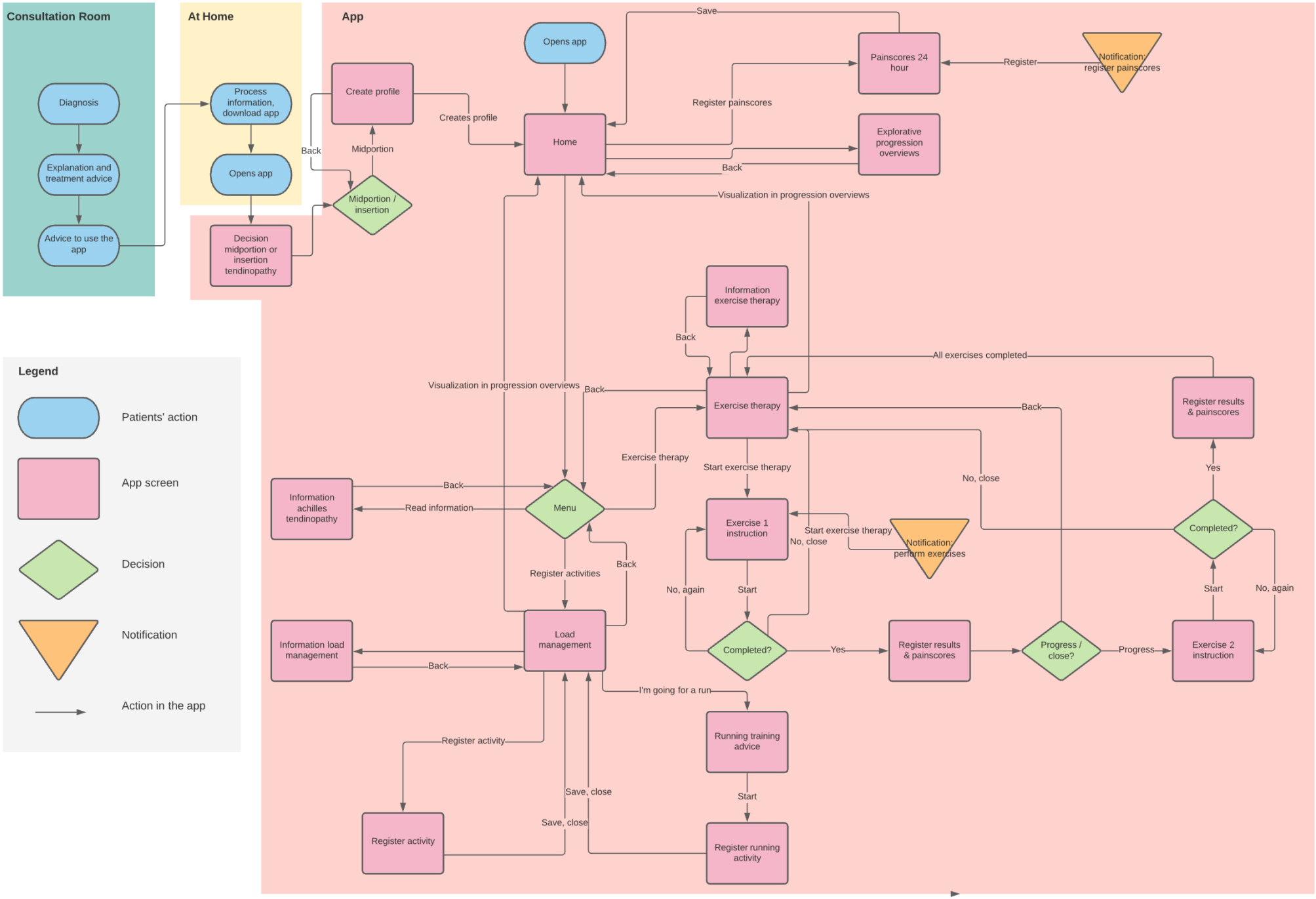


Figure I - User Flow Diagram

The patient journey and user flow diagram helped to identify the relevant features and content of the application. We chose to make the most relevant selection of features and content that will be developed in the prototype application. This selection was used to compose the screens that are fundamental for the application, which resulted in the following set of screens:

- Choice between midportion or insertional AT;
- Create a personal profile;
- Home with progression overviews and personal advices
- Weekly progression overviews
- Registration of pain scores
- Exercise therapy (main)
- Information exercise therapy
- Daily exercise therapy program
- Registration of exercises
- Sports and activities (main)
- Information sports and activities
- Registration of sports and activities
- Advice running training
- General information AT

Subsequently, a flowchart of the application structure was constructed, which shows the connections between the application screens. This was relevant in the further development of the application for the treatment of AT. The flowchart is visualized in Figure II.

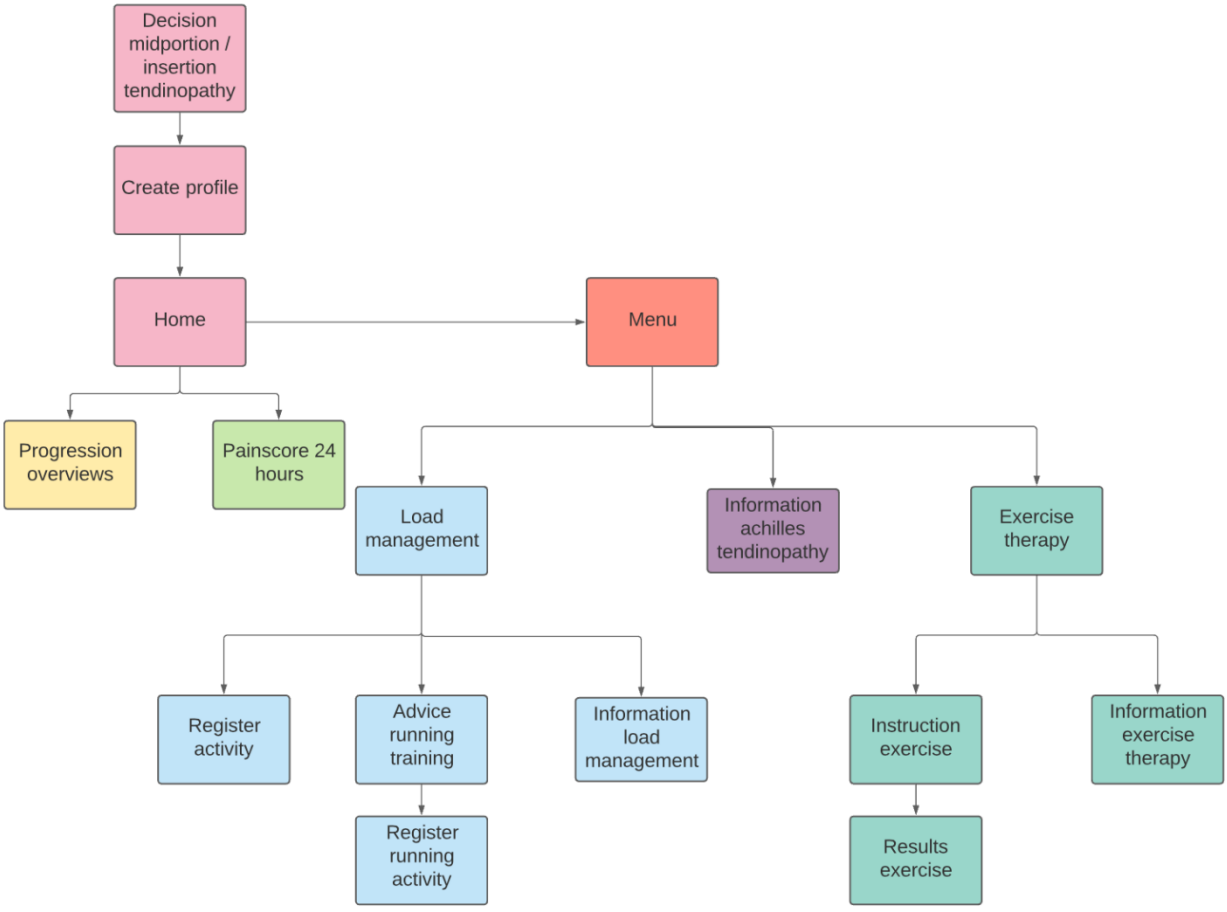


Figure II - Flowchart

2.6 Wireframes

The next step in the development of the prototype application, was wireframing in the form of basic black and white sketches of screen interfaces. Wireframes outline the different elements on the screen, as textual information, buttons and videos. This step is useful to understand the functionality of the application and to develop an interactive prototype based on the user experience [13].
By sketching the screens, we experienced that the screens are clearest when there are not too many features on the screens and the amount of textual information on the screens is limited. The information has to be provided in multiple parts divided over more screens, to enable the patient to read the amount of information he or she wants. Moreover, a clear menu has to be visible on each screen, for easy and rapid navigation between the different screens of the application. Last, each screen needs the same structure, to make the application easy to use.
The wireframes were integrated in the flowchart and are visible in Appendix V.

2.7 Axure Prototype

Based on the input of patients, the knowledge and experience of a sports medicine physician, and the conducted wireframes and flowchart, an interactive prototype was built in Axure (Axure Software Solutions, Inc., San Diego, Californië) [14]. The prototype simulates a fictitious treatment trajectory of a patient and is therefore personalized for this patient. The patient is in week five of the treatment program and is training in phase 2 of the exercise therapy. The beginning of the treatment trajectory (week 5) was chosen, because this simplifies the understanding of the prototype by patients that are in the start of the treatment process. If the prototype would be based on a patient in the end stage of the treatment trajectory, it would have been more difficult for patients in the start of the treatment to give well-founded feedback. The prototype is available on https://lwvbr9.axshare.com. Log in data can be shared upon reasonable request.

2.8 Videos

One of the important features of the application is a daily exercise therapy program with clear exercise instructions. Therefore, we aimed to include short instruction videos in the application. Within the given time, it was not possible to record our own videos. Hence, we searched the internet for suitable videos. We reconstructed these videos with our own exercise instructions and included them in the exercise program in the application.
Moreover, we included informative videos in the application. Some of these videos were readily available from the Department of Orthopaedics and Sports Medicine at the Erasmus MC. Other videos were found at YouTube; irrelevant parts were cut and deleted, and new text was recorded and edited by the video.

2.9 Prototype Evaluation by Patients

To test the interactive prototype on usability, structure, design, content and features, the prototype was presented to 2 patients. At the beginning of the interview, a short introduction of the objectives of the application was given. The patient was informed about the fictitious trajectory of a patient integrated in the prototype and the content and features of the application were discussed. The interactive prototype application was displayed on a phone screen and given to the patient. The patient was instructed to communicate his or hers thoughts and ideas, while running through the application. First, the patient was asked to go through the application for 5 minutes. Second, the patient was asked to perform 5 tasks in the application. Patients had to create a personal profile, navigate to the daily exercise program and walk it through, navigate to the screen with information about AT, watch an advice for a running training and register his or her pain scores. The screen and patient were observed closely, and remarkable observations were noted. Afterwards, patients were asked questions assessing the structure, design, content, features and usability of the application. Moreover, the application was evaluated on its expected benefits. An interview guide was conducted, to support the conversation with the patients and to make sure important information was assembled. Appendix VI includes this interview guide.
The results of the interviews are discussed below.

2.9.1 Results Prototype Evaluation Patients

Not to all screens was navigated properly at once, which required further navigation to find the right screens to complete the tasks. Yet, both patients completed all tasks in the application quickly. One patient mentioned the struggle with registering only one (sports) activity, when creating a personal profile. Ideally, she wanted to register multiple activities. Both patients experienced difficulty with registration of the daily pain scores, because they struggled with navigating back to the home screen. They sometimes had the feeling that 'they were lost in the application', which indicates the need for improvement in structure and navigation in the application. Another remarkable observation, was the fact that both patients took a relative long time to experience each screen. This is expected to be due to the fact that there are many features and a lot of information on the screens.

However, both patients thought the application was easy to use, the overall aim of each screen was clear, the structure of the screens was good and the features were easy to find.
Moreover, both patients expected the application to be beneficial in the treatment of AT. They liked the features to receive personal advises, when given right after the registration of pain scores, exercises or (sports) activities.
They were also positive about the reminder notifications for exercise therapy and data registration. One patient desires to use the application once a day and therefore wants to receive one reminder notification to directly complete all tasks in the application. The other patient provided feedback on the fact that she had to complete a lot of tasks in the application; she came up with the idea to require the registration of the average pain scores, (sports) activities and steps per day only once a week. The registration of the results of exercise therapy was thought to be of the highest value and therefore she wanted to register these results on a daily basis.
When patients were asked when they would use the application, they answered they especially see the benefit of using the application in their treatment process during exercise therapy, but they said they wanted to use the application also during the build-up of their (sports) activities. One patient stated the idea of using the application for advices and registration of workouts and (sports) activities on a weekly basis, instead of on a daily basis.
Both patients mostly stated the benefit of the motivational aspect of the application.
They would download the application and use it on a daily basis. They would recommend the application to other patients.

The need for improvements was also stated by the assessed patients. The menu has to be larger and more outstanding. Also, the menu has to be uniform and located on the same spot on each screen.
The graphical overviews of average daily pain scores, exercises, (sports)activities and steps per day have to be bigger and clearer. The figures include a lot of information and are therefore hard to interpret.
One patient stated the excessive amount of textual information and indicated the need for more figures and videos in the application. The other patient thought the information to be a lot, but saw the advantages of the explained topics. She thought the information is clear and beneficial.
One patient suggested the implementation of a feature to communicate with a sports medicine physician or sports physiotherapist in the application. She thinks this feature would be beneficial in staying motivated and would be useful in asking questions about exercises, load management or workouts.

2.10 Prototype Evaluation by Healthcare Providers

Healthcare providers as sports medicine physicians, general practitioners and sport physiotherapists are also important in the future use of the application. These healthcare providers will first see the patients during consultation and then recommend the application to their patients. Therefore, evaluation of the application by healthcare providers is of great relevance. One sports medicine physician and one sports physiotherapist was asked to evaluate the prototype.
First, a short introduction to the objectives of the application was given. The content and features of the application were discussed and the healthcare provider was informed about the fictitious trajectory of a patient integrated in the prototype. The interactive prototype application was displayed on a phone

screen and given to the healthcare provider. They were asked to go through the application and share their thoughts and ideas. Afterwards, healthcare providers were asked to give feedback about the content and relevance of the application.
The results of the interviews are discussed below.

2.10.1 Results Prototype Evaluation Healthcare Providers

The assessed healthcare providers were positive about the prototype application and stated they would definitely use the application in the treatment of their patients.

The healthcare providers mentioned several required improvements.
First, there were some needed practical points for improvement. For the exercise therapy registration, it would be useful to enable the registration of more repetitions and sets of the exercises, because certain patients are highly motivated and will complete more exercises then indicated. Moreover, when registering the (sports) activities in the personal profile, it would be beneficial if patients can register more than one (sports) activity. This will be more patient friendly, since most patients practice more than one (sports) activity. Also, one healthcare provider mentioned that the font is too small in the text and figures and that there is a need for the subdivision of the text in multiple paragraphs. Thereby, he expected the term 'Load Management' to be non-intuitive for patients. He expected the term 'Sports & Activities' to be better and more intuitive. Besides, there was stated that the menu has to be bigger and more outstanding on the screen. This would simplify the navigation through the application. Last, one sports medicine physician mentioned the current required registration of time and distance for (sports)activities, is only suitable for endurance sports. For multiple other sports, as team sports or ball sports, this method of registration is not adequate and other measures are needed. For example, the rate of perceived exertion (RPE) can be useful to register team sports and/or ball sports.

Second, the healthcare providers mentioned multiple modifications to make the progression overviews clearer and more motivating. To make the registered data more motivating, it would be beneficial to add colours to the figures, advices and results. Green would mean that the patient has completed enough exercises, the advice is positive, the results are improving or the patient has registered a safe pain score. Red would mean the opposite and orange would mean the results are in-between. Besides, the healthcare providers thought it would be useful to have a clear overview of all completed exercises since treatment onset and to provide insight in the progression in weights used during exercises, as well as the phases of exercise therapy, since these are important aspects of the treatment process of AT.

Third, the healthcare providers mentioned some possibilities to make the application more personalized. The provided information about overweight would only be relevant for patients with a high BMI. Therefore, it would be useful to add the feature to calculate the patients' BMI based on the weight and height. Based on the resulting BMI, the information about overweight is displayed or not. The same thing can be done for the information about chronic pain and sensitization; this topic is only relevant for patients with a high risk of developing chronic pain or sensitization. Therefore, it would be an opportunity to let the sports medicine physician decide whether the patient is at high risk and the information about chronic pain and sensitization would be relevant for the patient or not. Based on this decision, the information is displayed. Therefore, it would be an opportunity to use questionnaires about sensitization, such as the central sensitization inventory (CSI) or the Keele STarT MSK tool to assess whether the patient is at high risk and the information about chronic pain and sensitization would be relevant for the patient or not [15,16].

Fourth, one assessed healthcare provider brought up the idea to update the patient data registered in the application, automatically to the patients' electronic medical record (EMR). This way, the sports medicine physician can easily assess the treatment results during a consultation with the patient. For patients, this will also lead to increased motivation for performing the exercises and registering their data.

Fifth, according to one healthcare provider, the usability of the application could be increased by centralizing the data registration features. According to this sports physiotherapist, data registration of the average daily pain scores, exercises, (sports) activities and steps per day, are the most important features of the application. Therefore, he recommends to include the data registration features on the home screen.

Last, one healthcare provider doubted about the fact that the application requires registration of 3 different pain scores; the average daily pain score, the pain scores related to exercises and the pain scores related to (sports) activities. For patients, this is time consuming and not insightful, while for healthcare providers these pain scores provide relevant information. Therefore, the assessed healthcare provider recommended to take the registration of these 3 different pain scores into consideration.

3. Results

Based on the feedback of the interviewed patients, a sports medicine physician and a sport physiotherapist, the interactive prototype was adjusted and improved. This resulted in a final interactive prototype application for the treatment of AT. A diagram of the structure of the final prototype is visible in Appendix VII. The interactive prototype is available on https://2e2sll.axshare.com and described below.

When the application is downloaded and opened for the first time, an introduction screen will appear. The patient has to select the type of Achilles tendon injury he or she is diagnosed with. This can be either midportion AT or insertional AT. The patient will make a choice and is forwarded to the next screen where a personal profile can be created. Personal information has to be registered, as name, age, sex, height and weight, as well as information about the main (sports) activity. Thereby, to create a personal profile, a profile picture can be uploaded.
When the personal profile is created, the home screen will appear. The home screen forms the basis of the application and is displayed directly when the patient opens the application (and already created a profile). Insight in progression and motivating are the most important aspects of the application, and therefore the patients' progression is directly displayed on the home screen. Graphical overviews of average daily pain scores, exercise therapy, (sports) activities and number of steps per day visualize the progression in these areas. The number of weeks since treatment onset and average percentage of completed exercises are provided. Moreover, on the home screen, it is possible to register the average daily pain scores and an overview of these pain scores is given. To increase treatment adherence, in the final application, patients would be reminded of registering their daily pain scores by notifications that are given at a set time when the daily pain scores are not yet been registered. Thereby, personal advices are given about the pain scores, exercise therapy, (sports) activities and the general daily physical activity, based on the registered data.
From the menu on the home screen, it is possible to navigate to the screen with general information about AT (Information), the screen about (sports) activities, load management and workouts (Sports and Activities) and the screen about exercise therapy (Exercise Therapy).
The 'Information' screen includes an informative video about tendinopathy. Moreover, general information is given about AT, how to cope with pain and the importance of having a healthy weight and lifestyle.
On the screen called 'Sports and Activities', an overview of the daily completed activities and corresponding pain scores is given, as well as a personal advices about the load management. Moreover, the daily completed steps and (sports) activities can be registered, and the entered data would be visualized in the overviews on the home screen in the application. Notifications are given when the patients have not yet registered their daily steps and/or (sports) activities at a set time. The screen 'Sports and Activities' also includes a running schedule, providing advices for running trainings. Moreover, it provides the opportunity to read more information about suitable load management for patients with AT.
The screen 'Exercise Therapy' provides an introduction video about the relevance of exercise therapy for tendinopathy. Thereby, information about the current status of exercise therapy is given; the patient

is showed the current phase of exercise therapy, the duration of the treatment and the daily percentage of completed exercises. Based on this percentage, the patient receives a supporting advice for the exercise therapy. The patient would get a reminding notification, when the exercises have not been completed yet at a set time. The daily exercise program can be started from this screen. The patient is guided through the daily exercise program and asked to register the results and pain scores belonging to the exercises. In the application, the results would be uploaded to the overview on the home screen. Moreover, a preview of all phases of the exercise therapy program can be seen. Last, the patient can choose to read additional information about the exercise therapy. This information includes topics as the different phases of exercise therapy, rules for building-up the exercises, how to manage the pain during exercises, potential guidance during exercise therapy by a sports physiotherapist and how to prevent from recurrence of AT.
On all screens, the menu is visible, to always have the opportunity to navigate to other screens or back to the home screen directly.
The design of the application is chosen to be in Erasmus MC style. Also, there is attempted to design uniform and clear screens, with graphics presenting evidential messages, alternated by textual information and videos.

4. Discussion

4.1 Interpretation of Results

The prototype application developed in this project, is an important step towards a mHealth application for the delivery of the combined treatment of AT. The use of a patient-specific application for the treatment of AT will likely contribute to improved clinical outcomes of AT, by offering motivational features, progression overviews, personal advices, possibilities to track pain scores, exercises, (sports)activities and steps per day, patient-oriented information and training schedules. These features in the application will likely increase patient self-management.
The steps taken in this project, were essential to develop a prototype application that is effective and accepted by patients and healthcare providers. The user-centered design method increases the likelihood that patients are able to understand the relevant treatment aspects and patients are more willing to use the application.
When the application is proven to be feasible and showed its clinical benefits in the treatment of AT, the use of an application for the treatment of many other tendinopathies can be considered, since most common tendinopathies are treated using similar principles.

4.2 Strengths and Limitations

This project resulted in a feasible prototype application for the delivery of the combined treatment of AT. The prototype application is based on the new Dutch multidisciplinary guideline ‘Achilles Tendinopathy’ with currently the highest evidential value for the treatment of AT. Besides, the most important stakeholders (patients and healthcare providers) were involved in all phases of the development of the prototype application.

Several limitations of this project should be mentioned.
First, due to limited time, it was not possible to develop a prototype application which patients could use in their treatment process for a certain period. In order to test the treatment feasibility when delivered using the application, this is an essential step before completing the application for the delivery of the combined treatment of AT. Moreover, because of time constraints there was decided to focus on one sport activity (running) for the data registration and training build-up in the application. To make the application suitable for a wider patient population, other ways of data registration and training schedules need to be implemented in the application.
Second, only a few patients and healthcare providers where involved in the user research, usability testing and evaluation of the application. All included patients were treated by sports medicine physician Dr. De Vos, who is the chairman of the new Dutch multidisciplinary guideline ‘Achilles Tendinopathy’. In clinical practice, Dr. De Vos treats his patients according to this guideline, which means that all patients involved, received analogous information with a certain amount of homogeneity. Patients

treated by other sports medicine physicians, sport physiotherapists or general practitioners, may receive heterogeneous information with variable contents. It would have been better to involve a larger patient group with varying diverse group of patients, to obtain results that are better generalizable for the entire patient population. Moreover, the number of assessed healthcare providers is small and the assessed healthcare providers work together very closely. Therefore, the results of the interviews with the healthcare providers, may be influenced by personal bias. For unbiased and generalizable evaluation of the prototype, a larger number of healthcare providers from various institutes and hospitals should have been assessed.
Third, the final interactive prototype was built in Axure, which is software for creating prototypes and specifications for websites and applications. In this project it was a suitable tool, because it is free and simple to develop a prototype that allows interactions. However, it has some limitations. Certain desired design requirements and features were not able to implement in the Axure prototype. For example, it was not possible to implement notifications, save data, create graphics and charts based on actual registered data and give personalized advices. Therefore, it was not possible to communicate all features and ideas to the patients and healthcare providers and to receive feedback on this.

4.3 Future Research

For future research, it is necessary to build an application with all desired design requirements and features. These are described below and summarized in Table 4.

Table 4 - List of Recommendations Final Application

Recommendations for the final application
Data saving of registered data by patients
Progression overviews that are automatically updated with the data registered by patients
Personalized advices based on personal patient data
Sending notifications for reminders of exercise therapy and registration of pain scores and (sports) activities
Decision tree with cut-off points to decide which advice is given at what moment, this will enable the opportunity to automatically give personal advices to the patients
Decision tree with cut-off points to decide which information is given to which patients, to personalize the information provided in the application (information about overweight, information about chronic pain and sensitization)
Decision tree with cut-off points to decide when progression to the next phase of exercise therapy is indicated, this will enable the opportunity to automatically progress the patient to the next phase of exercise therapy
An application version for athletic patients
An application version for non-athletic patients
Integration of the ACWR model
Integration of running training schedules
Integration of training schedules for multiple variant sports
Communication between the application and the patients' electronic medical record (EMR), to enable sports medicine physicians and sports physiotherapists having insight in the registered data
Automated uploading of steps per day from the patients' smartphone or pedometer to the application
Recording instruction videos for exercises and implementation of these videos in the application
Recording informative videos and implementation of these videos in the application
Including RPE as outcome measure for registration of (sports)activities

In terms of the development of the future application, it is needed to research the implementation of the following features.
First, the application should have the opportunity to save data the patient registers.
Second, the application should include the feature to send notifications.

Third, the application needs to be further personalized. The progression overviews on the home screen, should visualize the data registered by the patients. In terms of the personal advices, it is needed to make a decision tree with cut-off points to decide which advice is given at what moment and based on what data. Moreover, the information provided by the application should be more personalized. For example, the information about overweight is only relevant for patients with a high BMI. An idea is to compute the patients' BMI based on the registered weight and height, and to make a cut-off point above which the information about overweight is given. The same thing can be done with the information about pain and sensitization. There can be decided to only provide this information to patients who are on a higher risk of developing chronic pain. Moreover, in the application a distinction can be made between athletic and non-athletic patients. The information can be more focused on general daily load and activities for the non-athletic group and the information for athletic patients can be more focused on building up to the desired (sports) activity. Another feature that may be added to the application to make it more personalized, is the feature that the patient is automatically progressed to the next phase of exercise therapy based on the registered results and pain scores of the exercises.
Fourth, the feature to integrate the acute-to-chronic-workload (ACWR) model and running schedules, has to be explored, as well as the integration of training schedules for other (sports)activities.
Fifth, the use of the application will be more patient friendly, when the number of steps per day can be automatically uploaded from the patients' smartphone or pedometer. This function needs to be researched for the development of the future application.
Sixth, automatic communication features between the application and the patients' EMR have to be researched. This will provide insight in the registered patient data by the sports medicine physician or sports physiotherapist, which would be beneficial in the treatment of AT in terms of patient motivation and time efficiency during consultations.
Seventh, the use of RPE as outcome for registration of the (sports)activities needs to be considered. This outcome measure is relevant for multiple sports that are difficult to register with distance and time as measure for perceived exertion.

Another possibility for future work is to record our own instruction videos for the exercises. This will give the application a more professional impression.
For certain informational topics, there were currently no videos implemented in the prototype, because of the absence of suitable videos. Making own instruction videos bring the opportunity to decrease the amount of textual information in the application.

Furthermore, when the development of an application with all requirements and features is completed, the application needs extensive usability testing by patients. Patients will be shortly informed about the application and are then requested to use the application for 4 weeks. Afterwards, the patients will be interviewed and feedback for improvements is obtained. The user version of the Mobile App Rating Scale (uMARS) can be helpful to conduct an interview which will give the most relevant feedback.
Based on the feedback, the application can be modified. Moreover, in this research, the uptake percentage (how many patients are willing to start use the application), will be investigated.
The final version of the application will be used to test the treatment feasibility when delivered using the application and the clinical benefits of the application. An RCT is necessary to compare the results of the treatment of AT when delivered in the conventional way (by consultations, leaflets and information on websites), or by the application. Patients will be recruited at Dutch general practices, physiotherapy practices and sports medicine practices. Patients will be randomly divided over 2 treatment groups. One group will receive treatment in the conventional way; by consultations, leaflets and information. The other group will use the application during the treatment process. After 8 weeks of treatment, patients will be assessed on adherence rate to load management advices, adherence rate to exercise therapy, number of sessions the application is used, total time the application is used, Victorian Institute of Sports Assessment – Achilles (VISA-A) score, patient satisfaction, return to (sports)activities and pain on the Visual Analogue Scale (VAS). Also, questions evaluating the experiences of patients with the application will be asked. This RCT will desirably show improved treatment outcomes of AT when delivered by the application, compared to treatment outcomes when delivered in the conventional way.

5. Acknowledgements

We would like to thank all patients from the Department of Orthopedics and Sport Medicine wo where willing to provide user input in this project and we would like to thank Adam Weir and Edwin Visser as healthcare specialists for their useful feedback on the prototype.

6. References

1. ICON 2019: International Scientific Tendinopathy Symposium Consensus: Clinical Terminology. Scott A, Squier K, Alfredson H, Bahr R, Cook JL, Coombes B, de Vos RJ, Fu SN, Grimaldi A, Lewis JS, Maffulli N, Magnusson SP, Malliaras P, Mc Auliffe S, Oei EHG, Purdam CR, Rees JD, Rio EK, Gravare Silbernagel K, Speed C, Weir A, Wolf JM, Akker-Scheek IVD, Vicenzino BT, Zwerver J. Br J Sports Med. 2020 Mar;54(5):260-262.
2. Dutch multidisciplinary guideline on Achilles tendinopathy. de Vos RJ, van der Vlist AC, Zwerver J, Meuffels DE, Smithuis F, van Ingen R, van der Giesen F, Visser E, Balemans A, Pols M, Veen N, den Ouden M, Weir A.
3. Br J Sports Med. 2021 Jun 29:bjsports-2020-103867.de Jonge, S., van den Berg, C., de Vos, R. J., van der Heide, H. J., Weir, A., Verhaar, J. A., Bierma-Zeinstra, S. M., & Tol, J. L. (2011). Incidence of midportion Achilles tendinopathy in the general population. British journal of sports medicine, 45(13), 1026–1028. https://doi.org/10.1136/bjsports-2011-090342
4. Kujala, U. M., Sarna, S., & Kaprio, J. (2005). Cumulative incidence of achilles tendon rupture and tendinopathy in male former elite athletes. Clinical journal of sport medicine : official journal of the Canadian Academy of Sport Medicine, 15(3), 133–135. https://doi.org/10.1097/01.jsm.0000165347.55638.23
5. Rolf, C., & Movin, T. (1997). Etiology, histopathology, and outcome of surgery in achillodynia. Foot & ankle international, 18(9), 565–569. https://doi.org/10.1177/107110079701800906
6. Knapik, J. J., & Pope, R. (2020). Achilles Tendinopathy: Pathophysiology, Epidemiology, Diagnosis, Treatment, Prevention, and Screening. Journal of special operations medicine: a peer reviewed journal for SOF medical professionals, 20(1), 125–140.
7. De Vos, R.J. Afdeling Orthopedie & Sportgeneeskunde. Patiënt folder ‘Midportion Achilles tendinopathie’. https://www.erasmusmc.nl
8. Rijken, M., Jones, M., Heijmans, M., Dixon, A. Supporting self-management. In: E. Nolte, M. McKee (Eds.). Caring for people with chronic conditions: a health system perspective. Berkshire: Open University Press, 2008. 116-142
9. Najm A, Lempp H, Gossec L, Berenbaum F, Nikiphorou E. Needs, Experiences, and Views of People With Rheumatic and Musculoskeletal Diseases on Self-Management Mobile Health Apps: Mixed Methods Study. JMIR Mhealth Uhealth 2020;8(4):e14351. URL: https://mhealth.jmir.org/2020/4/e14351. DOI: 10.2196/14351
10. Tang, C., Lorenzi, N., Harle, C. A., Zhou, X., & Chen, Y. (2016). Interactive systems for patient-centered care to enhance patient engagement. Journal of the American Medical Informatics Association : JAMIA, 23(1), 2–4. https://doi.org/10.1093/jamia/ocv198
11. Microsoft. 1987. Microsoft Powerpoint. Retreived from https://www.microsoft.com/nl-nl/microsoft-365/powerpoint
12. SAP User Experience Community. 2016, November, 28. Scenes. Retrieved from https://experience.sap.com/designservices/resource/scenes
13. Chatterjee, A. (2018) Catalyst to creation: why wireframing is important in app development. https://www.fingent.com/blog/catalyst-creation-wireframing-important-app-development/
14. Axure Software Solutions, Inc. 2002. Axure. Retrieved from https://www.axure.com
15. Mayer, T. G., Neblett, R., Cohen, H., Howard, K. J., Choi, Y. H., Williams, M. J., Perez, Y., & Gatchel, R. J. (2012). The development and psychometric validation of the central sensitization inventory. Pain practice : the official journal of World Institute of Pain, 12(4), 276–285. https://doi.org/10.1111/j.1533-2500.2011.00493.x
16. Campbell, P., Hill, J. C., Protheroe, J., Afolabi, E. K., Lewis, M., Beardmore, R., Hay, E. M., Mallen, C. D., Bartlam, B., Saunders, B., van der Windt, D. A., Jowett, S., Foster, N. E., & Dunn, K. M. (2016). Keele Aches and Pains Study protocol: validity, acceptability, and feasibility of the Keele STarT MSK tool for subgrouping musculoskeletal patients in primary care. Journal of pain research, 9, 807–818. https://doi.org/10.2147/JPR.S116614

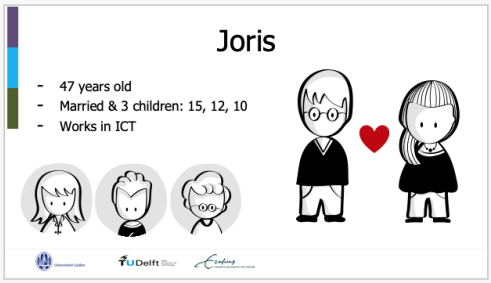
7. Appendices

7.1 Appendix I – User Scenario

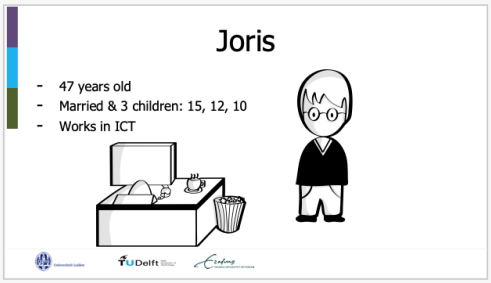
Joris (47) is married, has 3 children (15, 12, 10) and works full-time at an IT company. Because he sits a lot during his work, he likes to go for a run after work or in the evening (+/- 6-10 km) or for a ride on his racing bike (+/- 40 km). He does this about twice a week. On Sundays, he often goes for a longer ride (80-100 km) with a group of friends of the same age. Joris has been feeling his Achilles tendon while running for 2 months. And now even when he goes for a longer walk with his dog, his Achilles tendon starts to hurt. Joris thought it would pass with some rest and therefore he didn't sport for 3 weeks. When he started running again 2 weeks ago, the pain had not gone away. Rather, it seemed as if the pain had gotten worse. Joris has also been feeling pain in his Achilles tendon recently when cycling. This is reason for Joris to go to the doctor. The doctor tells him about the tendon injury he has; Achilles tendinopathy. The treatment consists of a clear explanation of the injury, doing exercises and Joris is also advised to temporarily replace running and cycling with activities where he is not in pain. The doctor also advises him to use an app that helps during the treatment of his injury. Joris would like to get rid of his injury as soon as possible, because sports are very important to him. He downloads the app, creates a profile and starts his treatment. Every day Joris receives a notification from the app with which exercises he has to do. There is a clear overview in the app with an instruction video. He uses the instruction videos to perform the exercises at home. Joris likes to see in the app that his adherence to therapy is 100%, when he has completed all the exercises. Every now and then Joris uses the app to go through the information contained in the information pages. He does this, for example, in the evening on the couch or in the morning during his breakfast. He feels that he now understands his injury better and he also understands the importance of doing the right exercises and building up his activities slowly. Because Joris is not allowed to run and cycle now, he goes for a walk (+/- 1 hour) every evening. He always feels his Achilles tendon and he is disappointed about that. He registers his walking activities in the app. Every now and then Joris also goes for a bike ride; he sticks to a small round of 30 km. He also suffers from this from time to time. Every evening Joris receives a message that he has to fill in his pain score for that day. He should also keep track of his pain score related to the exercises or his activity. Joris hopes to quickly see a decrease in pain in the progression overview. He also wants to make rapid progress and move on to the next stages of exercise therapy. He has read in the information pages in the app that he can proceed to the next phase if he can do all the exercises with a maximum pain score of 3. Joris hopes to see a reduction in pain soon, but after 6 weeks, he gets a notification from the app that his pain scores are increasing, while he is not making progress in his exercise therapy. The app teaches him that this may be because he is still overloading his Achilles tendon with other activities. Joris is very disappointed about this, but he understands that he has to adjust his daily activities further; he has to shorten his walks and he has to temporarily stop cycling. Now that he's done this, the exercises are going a lot better. After 10 weeks he is already training in phase IV of the exercises and his average daily pain scores are gradually decreasing. Slowly Joris gets to work extending his walks. He also cycles once in a while. This is completely painless. Joris learns from the app that he can start running again at the end of phase IV. According to the app, it is best to use a training schedule for beginners for this. Joris knows that he is not a beginner, but he also knows that he should not want to build up too quickly, because then there is a chance that the injury will come back. After completing this scheme, he will start using the ACWR model that the app offers him. In this schedule in the app, he can fill in his weekly running distance. The model then shows him whether he is training in the right form of load, to avoid overloading and underloading. Based on the model, he can plan his workouts, within the appropriate limits of load. He also uses the pain-monitoring model from the app. This model says how many rest days are needed after each workout. Because of the support that the app offers him during his treatment, Joris is very aware of the treatment process and feels confident in doing the exercises and building up his activities. By also consciously working on pain scores, Joris sees the effects of his training sessions, which motivates him to progress or to take a step back where necessary. After 5 months Joris can fully run again and cycle what he wants. He does a number of exercises from the app every week to prevent the injury from coming back. Joris is very happy with the result!

7.2 Appendix II – Visual Presentation User Scenario

1

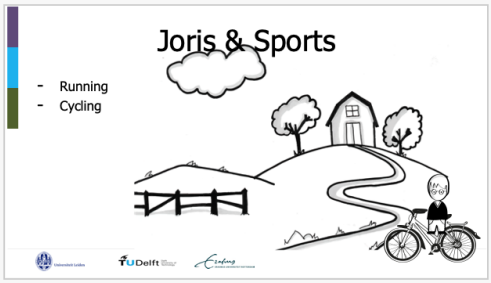


2

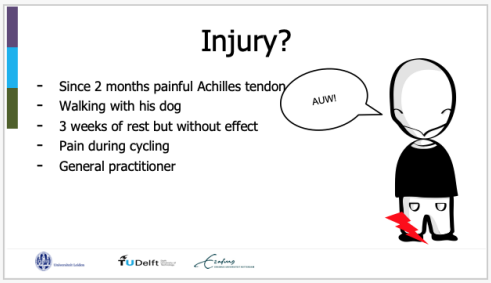


3

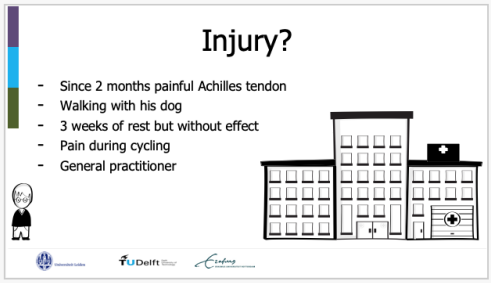
4



5

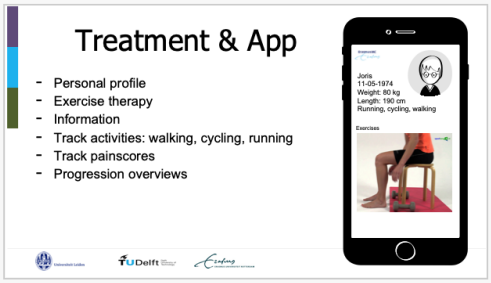


6



7

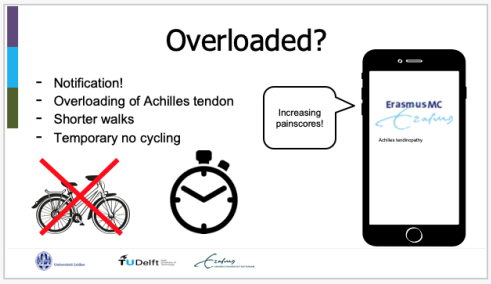
8



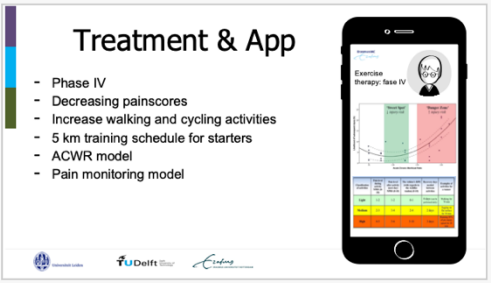
9

10

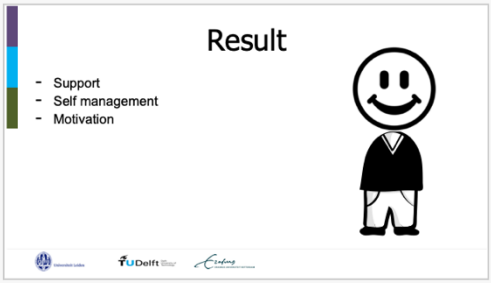
11



12



13



14

7.3 Appendix III – Interview Guide User Research

Introduction

The aim of this research is to develop an app for the treatment of Achilles tendinopathy. We expect that this would improve treatment outcomes. The app will be used to share information with patients, to provide an overview and clear instructions of the exercises, to support load management and to structure (sports) activities. Pain scores will be monitored. We expect that the app will help patients with Achilles tendinopathy to better organize their treatment themselves, which will lead to a better treatment outcome.

In this interview I will ask you questions about your experiences with the treatment of your Achilles tendon injury. The questions will also be about how you will envision the use of an app. You can answer these questions based on your own experiences and the scenario. In this way we will learn more about how you envision the use of the app as a user. This will help us in the further design of the app.

Patient characteristics

Patient code:
Age:
Sex:

1. Which (sports) activities do you normally practice?
2. Are you currently performing exercises for your Achilles tendon injury? If so, can you describe what exercises you are performing?
3. Which (sports) activities do you perform in addition to your exercise therapy?
4. Are you already building up your normal (sports) activities?
5. What goals do you want to achieve with the treatment of your Achilles tendon injury?

Achilles tendinopathy

1. Can you explain in your own words what your Achilles tendon injury is and how it can be treated best?
2. Do you feel like you understand what your Achilles tendon injury is and how it can be treated best?

Treatment

1. Can you tell us about your experience with the treatment of your Achilles tendon injury?
2. Do you feel like the treatment is effective?
3. How do you like performing the exercises?
4. How do you feel about being temporarily unable to practice your sport?
5. How do you feel about the information you have been given about your Achilles tendon injury?
6. Do you feel that you are well motivated to train?
7. What difficulties do you experience during the treatment of your Achilles tendon injury?
8. What positive experiences do you experience from the treatment of your Achilles tendon injury?
9. Do you have the feeling that the treatment (exercise therapy, adjusting the load, building up the (sports) activities) already has or will have positive effects?
10. How often do you skip your exercises?

App

1. Would using an app while treating an Achilles tendon injury be right for you?
2. What do you expect to be beneficial of using an Achilles tendon injury treatment app?
3. How do you envision using the app? (How often, where, would you like to receive messages, what kind of messages would you like to receive, what would you like to use the app for)
4. How do you think an app could help you better understand your injury and better organize your treatment yourself?
5. How do you think an app could help you during your exercise therapy? (For example: clear explanations and instructional videos, reminders for exercise therapy, progression to the next phase of exercise therapy, etc.)
6. How do you think an app could help you adjust your tax?
7. How do you think an app could help you build up your (sports) activities?
8. Would it be of added value if you could track and view your progress in exercises and sports load?
9. What functionalities do you think should definitely be in the app? Make a top 3.
    - Information about Achilles tendon injuries, exercise therapy, load management
    - Clear explanation exercises
    - Communication options
    - Keeping track of progress in exercise therapy and (sports) load
    - Experiences of others
    - Training schedules for building sports

- Functionalities that motivate me to perform exercises
- Overview of exercises per day
- Ability to track exercises
- Ability to keep track of (sports) activities
- Ability to track pain scores

10. Do you think you would use the app if it is developed? On a scale of 1 (definitely not) to 5 (definitely). Why?

7.4 Appendix IV – Patient Journey

A patient is diagnosed with 'Achilles tendinopathy' in the doctor's office. Here he receives explanations and advice about the treatment. The sports doctor recommends using an app during the treatment of the injury. This app helps during exercise therapy by providing clear instructions including a video of the exercises, giving a notification when exercises need to be done, keeping pain scores with the exercises and the possibility to track the progress of exercise therapy. The app is also useful for monitoring the activities in a day and building up the sports load. The app gives advice about the activities and training sessions on a day based on (sports) activities that can be completed and tracked. There are also links to pages containing additional information about Achilles tendinopathy and its treatment.

The patient goes home, lets the information sink in, reads the folder and downloads the app. At a quiet moment, he opens the app and arrives at the start page, where a choice must be made about the type of Achilles tendon injury the patient has. Based on the leaflet that the patient has received from the sports doctor, the patient opts for 'mid-portion' Achilles tendinopathy. The patient comes to a page to create a profile. The name, age, height, weight and sports activities can be entered on this. The profile is saved and the home page appears. Several things are visible on the home page. The patient sees his/her profile, an overview of the pain scores, exercises and (sports) activities of the past week and the patient can fill in his/her pain score of the past 24 hours. If a more extensive overview of the pain scores, exercises and (sports) activities is pressed, this overview becomes visible over the entire period of the treatment and the progress can therefore be seen. Based on this, the app gives advice about the load on the tendon.

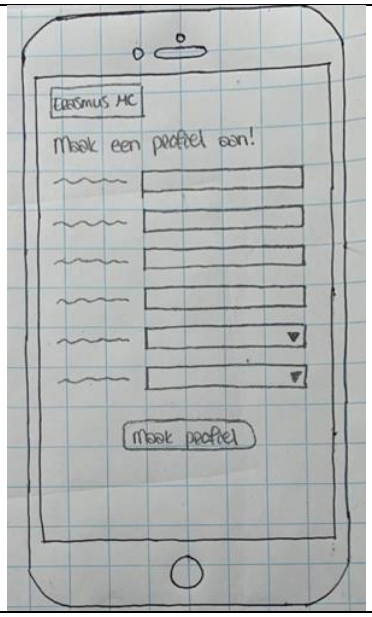
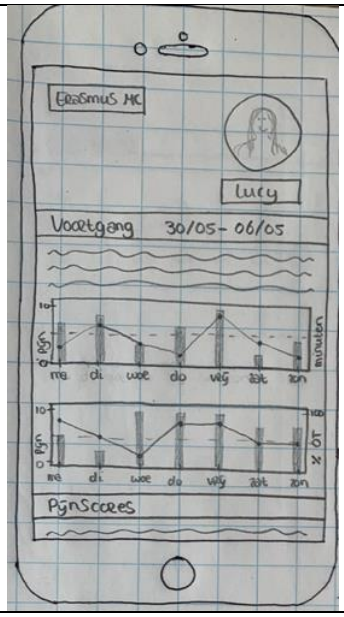
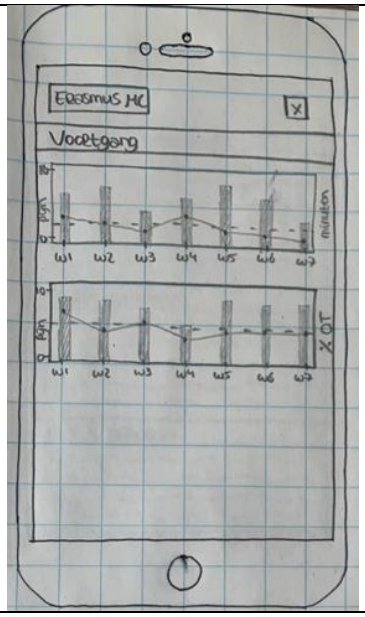
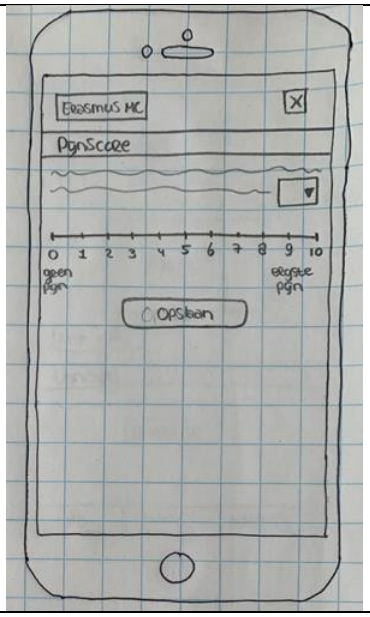
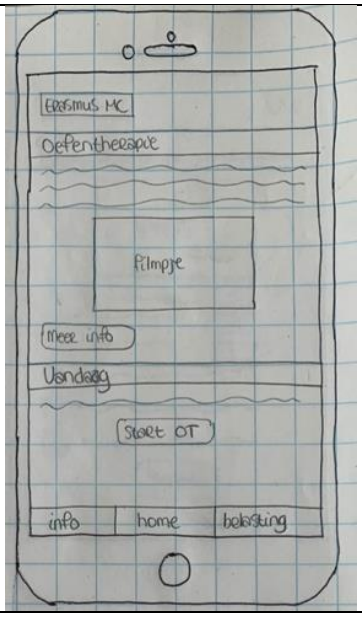
The patient would like to do the exercises for that day. In the menu on the home page, you can then choose 'Practice therapy'. The patient then arrives at the main exercise therapy page. This shows in which phase the patient is currently training, what percentage of the exercise program for that day has already been completed, can be selected to start the exercises and can also be selected for additional information about the exercise therapy. The patient sees that he is starting training in phase I of exercise therapy. He wants to start his exercises right away and chooses 'Start exercise program'. A page with instructions and a video of the first exercise will appear. Here the patient reads the short instructions and watches the video to make sure he is doing the exercise correctly. He also reads here that he must now do his exercises without weights. He presses 'Start' and he does the exercise. After completing the exercise, he can enter his number of sets completed, reps, weight used, and pain score. He then has the option to continue with the exercise program, or to close the exercise program. The patient feels that it is better to do all the exercises in succession and moves on to the second exercise. Again, a short instruction and a clear video will appear. He also completes this exercise and the corresponding data is entered. A screen will appear indicating that day's exercise program has been completed and the patient will be returned to the main exercise therapy screen. Here he sees that he has completed 100% of that day's exercise program. The patient is then curious about the function of the exercises he has performed. He clicks on the button for additional information about the exercises. Here he will find, among other things, an explanation about the function of the exercises. He finds this interesting to read.

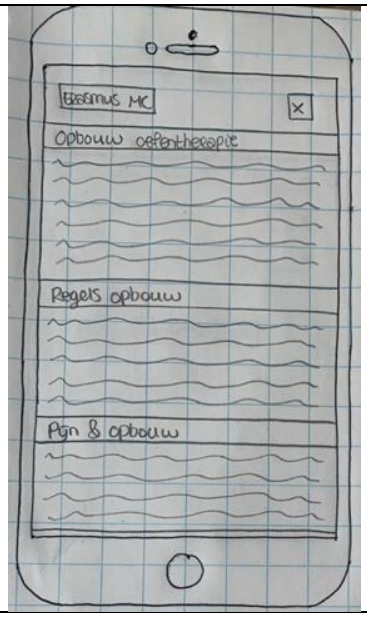
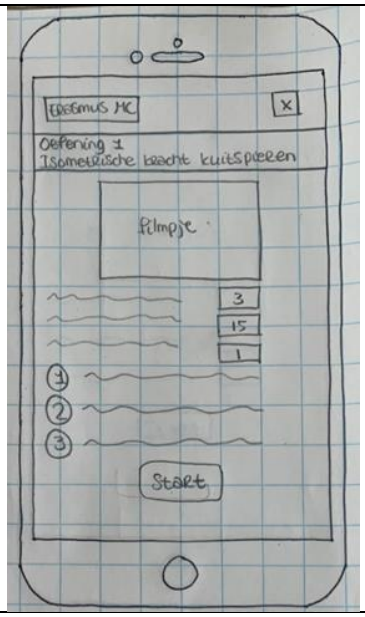
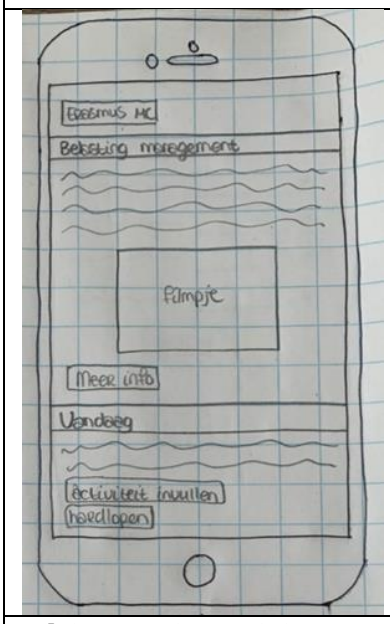
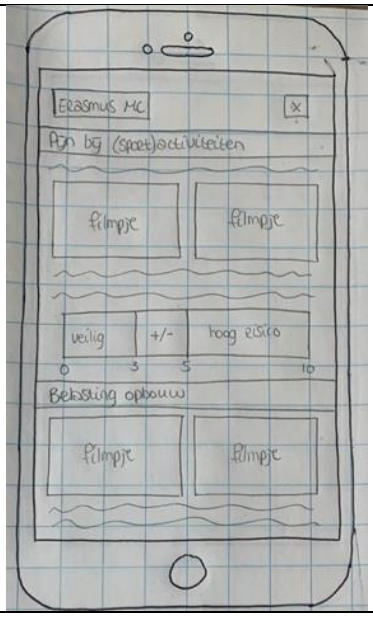
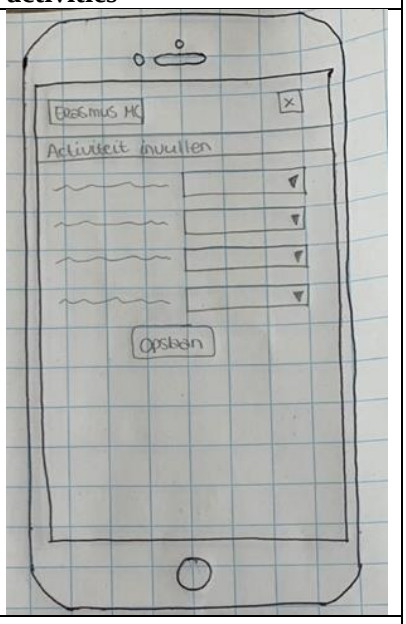
The patient also wants to fill in which activities he performed today. That is why he returns to the home page and clicks on 'Tax management' in the menu. He will be redirected to the main page tax management and here is the option to read more information about the structure of sports activities and tax management. He sees that he has no completed activities for that day and therefore wants to do this immediately. He clicks on 'Enter activity' and a page appears where he can fill in various information about his activity, such as type of activity, duration, distance and a factor for how hard the activity was. The pain score related to this activity is also entered. He presses 'Save' and is sent back to the main tax management screen. Here he then sees that the app gives advice based on the activities he did that day and the associated pain scores. The app says he has over-stressed his tendon and should choose activities the next day that are less taxing. Because he would like to know how this overload came about and which activities he could replace, he wants more information about his tax management. He clicks on the button and a page appears with detailed explanations about tax management. He learns that he can, for example, go cycling, so that he can still move without putting too much strain on his tendon. When he returns to the main load management screen, he sees that he can also get advice for a running activity. When he presses it, he is advised that it is still too early to build up running. He reads that he can start on this when he has completed phase IV of the exercise therapy. It returns to the main tax management screen and from there back to the home page. There he sees that his completed exercises and activities have become visible in the progress overview. He closes the app.

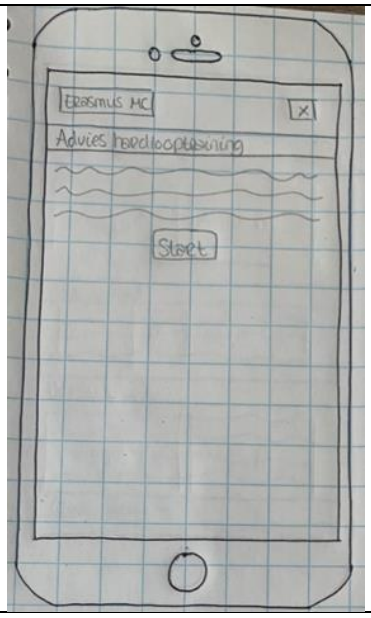
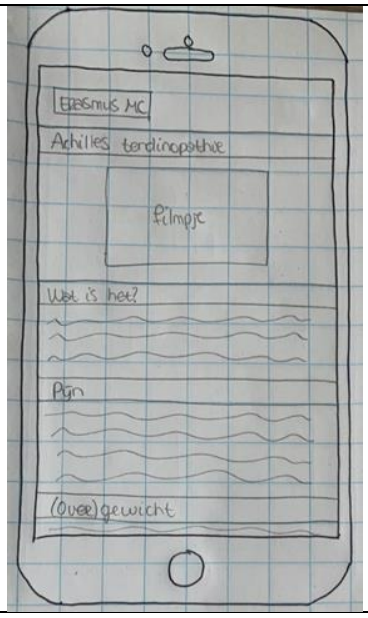
That evening at 9:00 pm, the patient receives a message from the app that he still has to fill in his average pain score for the past 24 hours. He opens the notification and immediately lands on the page where he can enter his pain score. When he clicks on 'Save' he is redirected to the home page, where his pain score is immediately displayed in the progress overview. He also sees a message there that he still has to fill in his daily amount of steps. He clicks on this and is redirected to the 'Fill in activity' page. Here he can enter his amount of steps and this also appears in the progress overview. He closes the app.

The patient uses the app on a daily basis to do his exercises, fill in activities and keep track of his number of steps. He likes to see the results immediately in the progress overview on the home page. Here he can clearly see when he has done something too much.
On busy days, the patient may forget his exercises. In the evening at 9 p.m. he receives a message that he still has to do his exercises. He is then happy to be reminded and opens the notification immediately. He clicks on “Start Exercises” and immediately completes his exercise program for that day. After this, he immediately fills in his pain score of the past 24 hours on the home page. He closes the app again.
After 3 weeks, the patient wants to start his exercise program for that day. He sees in the main screen of 'Exercise therapy' that he can proceed to the next phase of exercises. It sounds on "Start Exercise Program" and the exercises are automatically changed to Phase II exercises. He completes these exercises and again fills in his pain scores.
After 4 months, the patient is training in phase IV of his exercise therapy. He reads on the main load management screen that he can start building up his running workouts. That afternoon he opens the app and goes to the tax management page. He clicks on "I'm going for a run" and a page appears with advice for his first run. He starts this training and afterwards he can fill in details of his training. He fills in the distance, time and pain score. When he presses save, he is returned to the main load management screen. The next day's load advice has been adjusted based on the running activity he did. This gives him the feeling that he can build up running in a controlled manner, without directly overloading his tendon.
For example, the patient uses the app when he has to do exercises, has to fill in his average pain score or has undertaken a (sports) activity. He is very happy with the app and feels more confident in his own treatment. When he has completed the running schedule, he will receive a message from the app that he has recovered from his injury with the advice that he can slowly build up his activities and that it is wise to repeat the phase III exercises a few times a week. keep performing. The patient is happy that he has recovered and intends to continue doing the exercises from time to time.

7.5 Appendix V – Wireframes (Dutch)

Choice between midportion or insertional AT	**Create a personal profile**	**Home with progression overviews and personal advices**
		
Weekly progression overviews	**Registration of pain scores**	**Exercise therapy (main)**
		
Information exercise therapy	**Daily exercise therapy program**	**Registration of exercises**

		
Sports and activities (main)	**Information sports and activities**	**Registration of sports and activities**
		
Advice running training	**General information AT**	

 Erasmus MC Advies hardloopbehandeling Start	 Erasmus MC Achilles tendinopathie Filmpje Wat is het? Pijn (Over)gewicht	

7.6 Appendix VI – Interview Guide Prototype Evaluation

Introduction

The aim of this research is to develop an app for the treatment of Achilles tendinopathy. We expect that this will improve the outcomes of the treatment.

Features of the app:

- Share information with patients
- Overview exercises with clear instructions
- Exercise program that the patient is guided through
- Advice on tax and (sports) activities
- Advice based on (sports) activities, steps, exercises, pain scores
- Keep track of (sports) activities
- Track steps
- Keep pain scores
- Exercise tracking with pain scores
- Notifications with exercise therapy reminder
- Notifications with pain score reminder

We expect that the app will help patients with Achilles tendinopathy to better organize their treatment themselves, which will lead to a better result of the treatment and less healthcare consumption.

This prototype mimics a fictitious trajectory of a patient. The patient trains in phase 2 of the exercise program and is on the treatment for 5 weeks.

Patient characteristics

Age:_____

Sex:_____

1. Do you practice sports activities? If so, what sports activities do you normally practice? How many times a week do you practice this sport? How long are your workouts?
2. Are you currently performing exercises for your Achilles tendon injury or have you done any exercises? If so, can you describe which exercises?
3. Which (sports) activities do currently you practice? How many times a week do you practice this sport? How long are your workouts?
4. What goals do you want to achieve with the treatment of your Achilles tendon injury?

Tasks

Perform the following actions. Think out loud, say why you make certain choices, what you are looking for and why you press certain buttons.

- Create a personal profile
- Start today's exercise program and go through it
- Navigate to the Achilles tendon injury information
- View advice for your running training
- Enter your average pain score today

Structure app

1. Can you easily find the functions you are looking for?
2. Is it clear what the purpose of each app screen is?
3. Is the app easy to use? Is it easy to learn to use the app?

Design of app screens

1. Do you think the app looks attractive?
2. What do you think of the structure and structure of the app screens?

Information & text

1. What do you think of de application of information?

□ A lot □ Few
□ Clear □ Not clear
□ Useful □ Not useful

2. Can you easily find the information you are looking for?

Functionalities & notifications

These questions are about functionalities that will eventually be added to the app, but that are not yet built into the prototype.

1. What functionality do you think could be added to the app?
2. In the prototype, the steps must be completed manually. Ultimately, it would be an idea that the phone's pedometer is connected to the app, automatically loading the number of steps to the app if you give permission. How would you like it if your pedometer on your phone is automatically linked to the app?
3. How would you like to get advice notifications from the app? For example, advice about whether you can build up your (sports) load or that you should take it easy? How many of these types of notifications would you like to receive per day?
4. How would you like to get notifications with reminders from the app? For example, a reminder for your exercise therapy or for filling in your pain scores? How many of these types of notifications would you like to receive per day?
5. Pain scores, results of the exercise program and (sports) activities must be entered per day, how do you think this is? How many of these results would you like to fill in per day?
6. Would you like to share data from the app (for example, the exercises done, the number of steps taken per day, the pain scores) for research purposes with doctors at the hospital if your data is stored anonymously? Why?
   1 = no 2 = probably not 3 = maybe 4 = probably 5 = yes

General

1. What do you think of the app?
2. At what stage of your treatment would you like to use the app? (For example, after the exercises have been completed, when building up with the sport, etc.)
3. Would the app support you in your treatment? Why?
   1 = no 2 = a little bit 3 = a bit 4 = quite a bit 5 = yes
4. Would the app help motivate you to do your treatment well? Why?
   1 = no 2 = a little bit 3 = a bit 4 = quite a bit 5 = yes
5. Would the app help you organize your (sports) activities? Why?
   1 = no 2 = a little bit 3 = a bit 4 = quite a bit 5 = yes
6. Would the app give you more insight into regulating and building your tax? Why?
   1 = no 2 = a little bit 3 = a bit 4 = quite a bit 5 = yes
7. Would the app help you do the exercise therapy? Why?
   1 = no 2 = a little bit 3 = a bit 4 = quite a bit 5 = yes
8. Would you download the app? Why?
   1 = no 2 = probably not 3 = maybe 4 = probably 5 = yes
9. Would you use the app daily as intended? Why?
   1 = no 2 = probably not 3 = maybe 4 = probably 5 = yes
10. Would you recommend the app to others? Why?
    1 = no 2 = probably not 3 = maybe 4 = probably 5 = yes

7.8 Appendix VII – Diagram Final Prototype