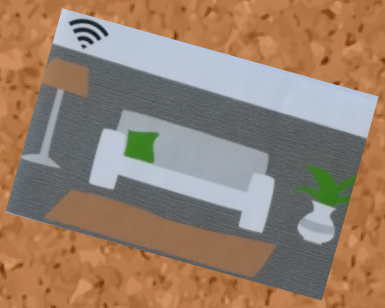
REshape Center

Radboudumc

Supervisor: Tom van de Belt, PhD



Sticky Exercises

Frequency and quality optimisation of rehabilitation exercises using location specific reminders and video instructions via a smartphone application.

Research internship

05-02-2018 - 14-09-2018

Jolijn van Uden

S4333330

Abstract

Background: Poor adherence and low quality of home exercises in physiotherapy negatively affect treatment outcomes. As a solution, a digital intervention called Sticky Exercises was developed consisting of location specific visual reminders and a smartphone application. It aims to enhance self-efficacy which is related to adherence and clinical outcomes.

Study aim: Study the potential effect of the Sticky Exercises intervention on self-efficacy and map user experiences.

Methods: Patients with neuralgic amyotrophy or other shoulder complaints and prosthesis wearers were included. An intervention group used the solution for four weeks and a control group rehabilitated as usual. At baseline and after four weeks self-efficacy was assessed. System usability scores, qualitative data from interviews, scanning frequencies and pain and confidence levels from users were collected and analyzed as well.

Results: Data of eighteen participants was analyzed. There was a significant difference in self-efficacy in the NA or other shoulder complaints group (p=0,048), but not in the prosthesis group (p=0,343).The mean system usability score was 80,8 (±13,7) and the mean overall grade 7,8 (±1,3). Most participants scanned less frequent than indicated. There was hardly any change in pain and confidence levels. Barriers, facilitators and effects were collected, as well as suggestions for improvement.

Conclusion: Using sticky exercises lead to an increased self-efficacy in patients with NA or other shoulder complaints, but not in prosthesis wearers. Usability was highly acceptable and users were positive about the intervention and stated that it positively affected their recovery.

Contents

Introduction

It is known that physiotherapy adherence is generally very poor, particularly for prescribed home exercises(1-4). Since low adherence negatively affects treatment outcomes(4-8), multiple studies examined factors that affect adherence. They report that patients experience barriers related to time constraints, poor motivation to perform long exercises next to their daily activities and forgetting to perform their exercises(2, 9). Not only the frequency of doing of home exercises matters. The quality of home exercises is probably even more important. Research shows that individual instructions or feedback positively contributes to the quality or performance of home exercises (10, 11). Furthermore, it is known that the majority of people learn most efficiently by imitation(12). An important factor when it comes to adherence is a patient's self-efficacy (4, 7, 13-16). Therefore, interventions that increase a patient's self-efficacy might improve adherence and indirectly treatment outcomes(7, 17). Since e-Health or m-Health applications have great potential for inducing behavioural change by resolving encountered barriers(18-25), digital interventions might be effective in improving adherence(20, 23, 24). In the field of physiotherapy, using e-health applications have already shown to be feasible and acceptable(22, 25).

Based on the above mentioned principles, Radboudumc and Touchless Industries developed a home rehabilitation intervention called "Sticky Exercises". It consists of location specific visual reminders and a smartphone application. The physiotherapist prescribes relevant home exercises, integrated in daily activities, that can be executed at specific locations in the house. Reminder stickers, equipped with near field communication (NFC) technology , are placed on that locations. NFC technology facilitates contactless communication between two devices on short distances which is for example used in contactless payments with a bank card. When participants scan the NFC stickers with their smartphone they immediately see a video of themselves performing the exercise or a standard exercise video. This is accompanied with personal instructions from their physiotherapist. The aim of the solution is to enhance self-efficacy.

We selected two groups of patients to test and evaluate the intervention, patients with neuralgic amyotrophy (NA) or other shoulder complaints and patients with an osseointegrated leg prosthesis (OIP). These were chosen as both groups require intensive physiotherapy including home exercises for a long time to reduce residual complaints, prevent compensation strategies and increase activity level(26-29). However, they are very different in terms of type of disorder and physiotherapy approach. NA is a disorder with episodes of extreme pain, paresis and atrophy in muscles of the upper extremities due to acute nerve damage in the brachial plexus(30, 31). An episode takes four weeks on average with reported NRS pains scores >7, but after that initial period patients suffer from severe residual complaints(32). Moreover, recurrent attacks occur in 74.5% of the patients(32). In the Netherlands, the incidence of NA is 1 per 1000 per year(33). NA patients visit the outpatient clinic of the Radboudumc and attend to individual consultations with a physiotherapist. The OIP is a relatively new type of prosthesis offered in the Radboudumc in Nijmegen to patients who encounter problems with their socket prosthesis(34). The OIP is attached to the patient's bone with a metal plug. The incidence of lower limb amputation is 8.8 per 100.000 person-years(35). Patients who receive an OIP are enrolled in a six-week group rehabilitation program in the Radboudumc and after that they are referred to regular physiotherapy practices.

The aim of the present study was to study the potential effect of the Sticky Exercises intervention on self-efficacy and map user experiences.

Methods

Design and setting

In this exploratory study, the feasibility and acceptability of a movement rehabilitation intervention consisting of a smartphone app with location specific reminders and personalized instructional videos was assessed. The target population of the study was people with NA or other shoulder complaints and people with an OIP. Quantitative data about the change in self-efficacy, system usability, frequency of use and registered pain and confidence scores was obtained. Moreover, qualitative information regarding user experiences, factors influencing app usage and effects was obtained. The study was conducted at one of the larger academic clinics, the Radboudumc in Nijmegen, The Netherlands. The local medical ethical committee reviewed and approved the study protocol (ID 2017-3364).

Intervention

The rehabilitation intervention consisted of two components. The first involved location specific reminders to optimize the frequency of performing home exercises. They consisted of stickers, also called 'sticky reminders', and were placed on specific locations in their homes. Each location corresponded to a specific exercise, as determined by the physiotherapist. Figure 1 depicts the 'sticky reminders for three locations. Each 'sticky reminder' contained NFC technology, allowing it to communicate with the smartphone app described by component 2.

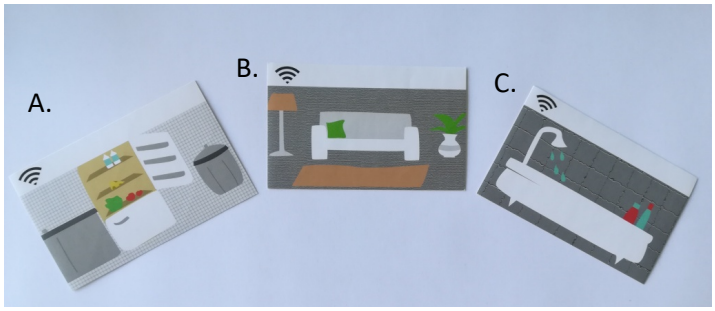


Figure 1. Example of the NFC stickers that were placed on specific locations in the participant's home. A. Kitchen, B. Living Room, C. Bathroom.

The second component consisted of a smartphone application containing videos of exercises with instructions from a physiotherapist. Each time a user would place his or her smartphone close to the visual reminder (component 1) he or she could view the video and simultaneously do home exercises. The video shows how to execute the exercise in the right manner. In the application there is also a daily feedback form containing questions about pain and confidence. When a participant forgot to fill this in, he or she received a push notification on the next morning. The application was protected with a username and password and an authentication code from the Google Authenticator application. Screenshots of the mobile application for patients and digital portal for health

professionals environment including exercises, timeline, pain and confidence charts and the feedback forms are presented in Appendix A.

Study procedures

Study participants

Patients with an OIP were recruited from the physiotherapy department of the Radboudumc. Patients with NA or other shoulder complaints were recruited from Kinos Rehabilitation, which is a rehabilitation facility specialized in complex shoulder problems. In- and exclusion criteria are listed in table 1.

Inclusion criteria	Exclusion criteria
NA or leg prosthesis	Age <18 years
Expected rehabilitation ≥ 4 weeks	Incapacitated person
Home exercises are part of rehabilitation program	Unstable medical situation due to co-morbidity, that negatively affects rehabilitation (determined by physiotherapist)
Ability to speak, read and understand Dutch	
Access to an NFC-compatible smartphone*	

*Table 1. In- and exclusion criteria for patients to be eligible to participate in the study. *only for the participants included in the intervention group. Participants in the control group did not have to meet this condition. NA = neuralgic amyotrophy. NFC = Near Field Communication.*

All study participants were invited to participate in the intervention group, but if their smartphone was not equipped with NFC technology they were asked to participate in the control group. The control group performed home exercises according to standard care and the intervention group performed home exercises with the help of the sticky exercises intervention.

Protocol

Patients were informed about the study by their own physiotherapist or a researcher. When they were willing to participate, signed informed consent was obtained. The study started during the next session with the physiotherapist. During this session, the physiotherapist determined which home exercises to perform in the four-week intervention period and on which location in the participant's home setting. On these locations the stickers would be placed. The exercises were practiced during this consultation. For participants with NA or other shoulder complaints videos were recorded of the patient doing the exercises while ensuring he or she was not identifiable for privacy reasons. In the prosthesis group standard videos of the exercises were selected, because it was not possible to capture the essence of performing the exercise without showing the participant's face. These standard videos were already used in regular care prior to this research. The participants were instructed to fill in the feedback form in the application on a daily basis.

Immediately after the session, a researcher supported participants with downloading and installing the app, gave a short introduction on how to use the app and provided them with the stickers. Also, the participants filled in the Exercise Self-Efficacy Scale (ESES) questionnaire complemented with questions about demographics of the participant. The ESES was used to calculate a score from 10-40

where 40 yields very high self-efficacy and 10 very low. The researcher added the exercise videos to the participant's account in the mobile application and coupled them to the right locations. After the visit the participants placed the stickers in their homes and at that moment the four week intervention period started. In this period the participants were instructed to perform their home exercises with the help of the sticky notes and the mobile application.

The physiotherapist was instructed to monitor the participant via a digital portal during the intervention period. When there were consultations scheduled during the intervention period a researcher was present again to record or select new videos and add them to the participant's account on the mobile application. At the end of the study, the application was removed from the participant's smartphone and the stickers were collected by the researcher. At this point, the participant filled in the ESES questionnaire once again and next to that the System Usability Scale (SUS) questionnaire. The SUS was used to calculate a score from 0-100 where 100 yields very good usability and 0 very poor. Furthermore, a semi structured interview was executed in which participants were asked for their user experiences with the intervention and to grade the overall system. Since the mobile application keeps track of the frequency of use and the pain and confidence scores, this could be analyzed as well. After the final consultation, the patient's regular rehabilitation program was continued. The specific timeline per participant is presented in figure 2.

For the participants in the control group the intervention period consisted of performing home exercises according to their regular rehabilitation program. Their self-efficacy was assessed with the ESES questionnaire before and after a period of four weeks.

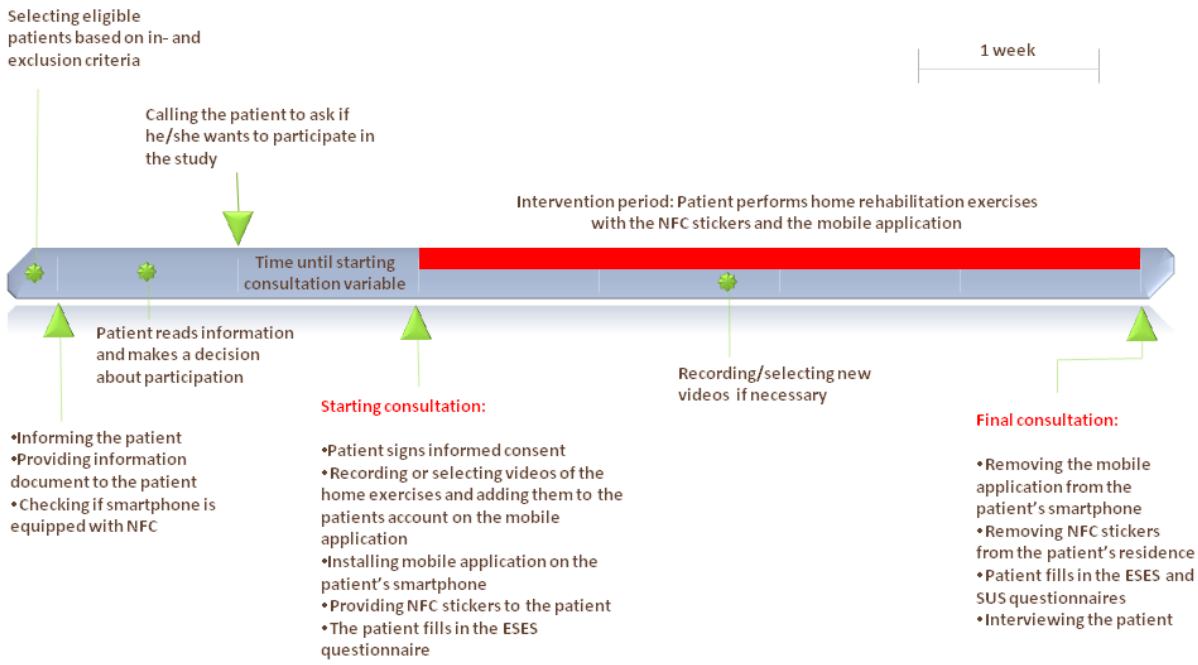


Figure 2. Timeline of the procedure. If a participant did not meet in- and exclusion criteria or declined participation, the procedure was discontinued immediately. If participants were assigned to the control group, they followed the same timeline, but without the intervention specific actions and measurements. Their intervention period consisted of performing home exercises according to their regular rehabilitation program.

After all participants completed the study procedure, physiotherapists that were involved with the treatment of participating patients were also invited for a semi-structured interview in order to obtain user experiences from the health professional perspective as well.

Data analysis

Quantitative data were analyzed using Statistical Package for the Social Sciences (IBM SPSS Statistics version 22, SPSS inc., Chicago, Illinois, USA). Since this research is an exploratory pilot study, no formal sample size calculation was calculated. We reasoned that a total of 20 study participants would be sufficient to answer the research questions of this exploratory study. Self-efficacy scores before and after the intervention were compared using the non-parametric Wilcoxon signed-rank test for related samples. The change in self-efficacy in the intervention group and in the control group was compared using the Mann-Whitney U test. P-values <0.05 were considered statistically significant. Individual self-efficacy scores at baseline and after four weeks complemented with mean scores were also visualized in bar charts. Answers to open ended questions were arranged in a table. System usability and overall grades were described using mean and standard deviation (SD). Individual scores and the mean of these scores were also shown in a bar chart. Scanning frequencies for every individual exercise were shown in a bar chart as percentages of the frequency indicated in the smartphone application. Individual time courses over the period of four weeks were shown in a graph with absolute frequencies compared to the indicated frequencies in the smartphone application. For the pain and confidence scores missing values were imputed using multiple imputation. Compliance of filling in the feedback form was shown in a bar chart as percentages of the instructed frequency of filling it in for every individual participant. Mean pain and confidence scores over time were plotted in a line chart and linear trendlines were added. The course over time of pain and confidence was described by the gradients of the trendlines. Correlations between self-efficacy, system usability, overall grades and frequency of use were assessed using Pearson correlations. Audio-recorded interviews were transcribed and transcripts were analyzed by two researchers independently, identifying barriers and facilitators that affected usage of the sticky exercises intervention and perceived positive and negative effects of the intervention. The results were discussed until consensus was reached and were arranged in a table. Barriers and facilitators were presented according to the framework of Gagnon et al and perceived positive and negative effects were presented following the Donabedian Framework for Quality of care (36, 37). Additionally, improvements suggested by participants for the future version of the system were identified and presented, as well as other relevant insights derived from the interviews.

Results

Patient characteristics

Nineteen study participants were included in this study, of which eleven in the intervention group and eight in the control group. One participant was excluded from all analyses due to an insufficient level of Dutch (reading) which became evident during the data collection phase. Of the remaining 18 participants that started the study, one participant was lost to follow up after four weeks and could therefore not be included in the ESES analyses. Another study participant from the intervention group never used the intervention and did not fill in the SUS questionnaire. For this person, all other outcome measures were collected. Characteristics of the 18 study participants included in the analysis are shown in table 2.

	Intervention group (N=10)	Control group (N=8)	Total (N=18)
Patient group			
Prosthesis	4 (40%)	5 (62,5%)	9 (50%)
NA/shoulder complaints	6 (60%)	3 (37,5%)	9 (50%)
Gender			
Man	8 (80%)	5 (62,5%)	13 (72,2%)
Age			
18-34 years	1 (10%)	2 (25%)	3 (16,7%)
18-34 years	1 (10%)	2 (25%)	3 (16,7%)
35-49 years	2 (20%)	1 (12,5%)	3 (16,7%)
50-65 years	6 (60%)	3 (37,5%)	9 (50%)
>65 years	1 (10%)	2 (25%)	3 (16,7%)
Education level			
Primary school	0 (0%)	2 (25%)	2 (11,1%)
Secondary school	2 (20%)	0 (0%)	2 (11,1%)
Intermediate vocational education (Dutch: MBO)	4 (40%)	3 (37,5%)	7 (38,9%)
Higher professional education (Dutch: HBO)	3 (30%)	2 (25%)	5 (27,8%)
University	1 (10%)	1 (12,5%)	2 (11,1%)
Physiotherapy			
Has had physiotherapy prior to current treatment	10 (100%)	8 (100%)	18 (100%)
Home exercises			
Already doing home exercises in current rehabilitation	10 (100%)	7 (87,5%)	17 (94,4%)

Table 2. Population characteristics. NA=neuralgic amyotrophy

Self-efficacy

Ten intervention group participants and seven control group participants filled in the ESES questionnaire at baseline and after four weeks of intervention period. One participant in the control group only filled it in at baseline. Self-efficacy scores were calculated for both time points and the difference between these scores was calculated as well. There was no statistically significant change in self-efficacy after four weeks both in the control group (p=0,595) and in the intervention group (p=0,108). When comparing the control and intervention group there was no significant difference found in the change of self-efficacy (p=0,161). However, we also analyzed the NA or other shoulder complaints group and the prosthesis group separately. This revealed a significant larger change in self-efficacy in the intervention group compared to the control group in the NA or other shoulder complaints group (p=0,048). In the prosthesis group there was no significant difference (p=0,343). A visualisation of the individual self-efficacy scores is attached in Appendix B.

In the ESES questionnaire there were also open ended questions about aspects that affected confidence and insecurity in the rehabilitation. Answers were very diverse. A common remark was that participants felt confident because they were taught how to move in the right manner by their therapists and they noticed improvement in their rehabilitation. A lot of participants did not mention any factors affecting their insecurity and the answers that were given were diverse. The complete list of answers is attached in Appendix C.

System usability

System usability scores and overall grades are depicted in figure 3. The mean SUS score was 80,8 (±13,7) and the mean overall grade was 7,8 (±1,3).

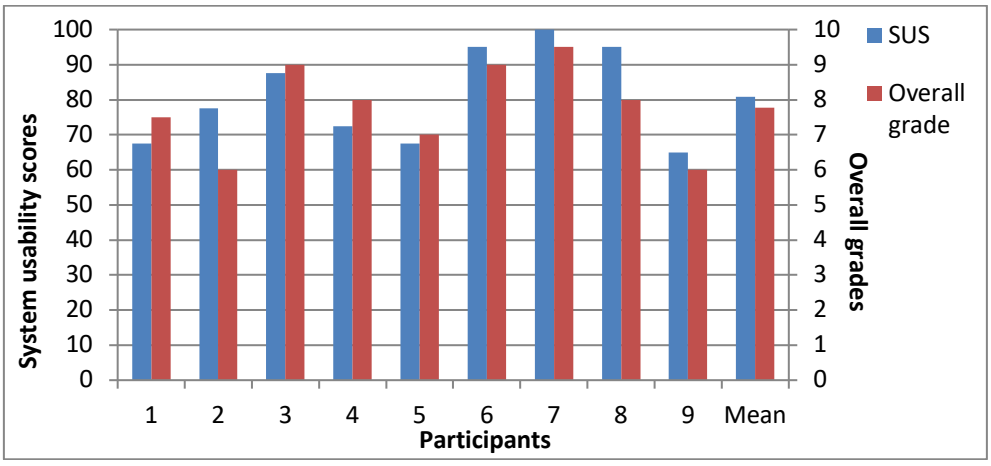


Figure 3. System usability scores and overall grades. The NA or other shoulder complaints group consisted of study participants 1-6 and the prosthesis group consisted of study participants 7-10. N=9. SUS= system usability scale

Frequency of use

All but one participant used the application, but there was a lot of variation in scanning frequencies between subjects. There were also small variations in the different exercises within one participant. Only one participant scanned more often than was indicated; most participants scanned less frequent than was indicated. Figure 4 illustrates the scanning frequencies in more detail.

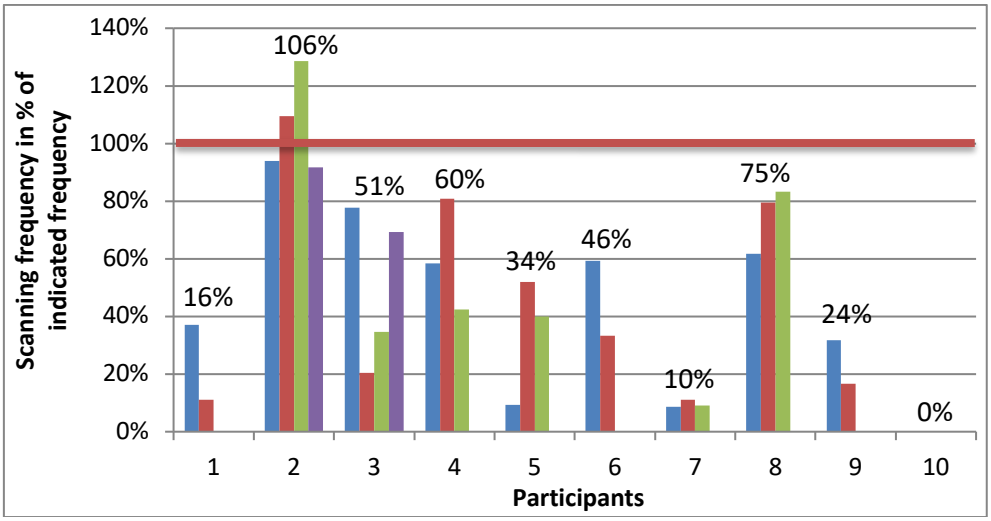


Figure 4. The extent to which the scanning frequency of participants matched with the indicated frequency. Coloured bars represent the scanning frequency of the tags belonging to the different exercises patients had to do. The red line represents the indicated frequency of doing the exercises. Indicated percentages are the means of all exercises. The NA or other shoulder complaints group consisted of study participants 1-6 and the prosthesis group consisted of study participants 7-10.

To see the differences between study participants and the course over time, individual scanning frequencies are shown in figure 5. These figures show the large variation among participants. Some participants scanned almost daily, but others scanned only incidentally. One subject did not scan the tags anymore after two weeks and one other subject took almost a week before starting with scanning. In the other subjects scanning frequencies were quite stable. We did not see a decline over time.

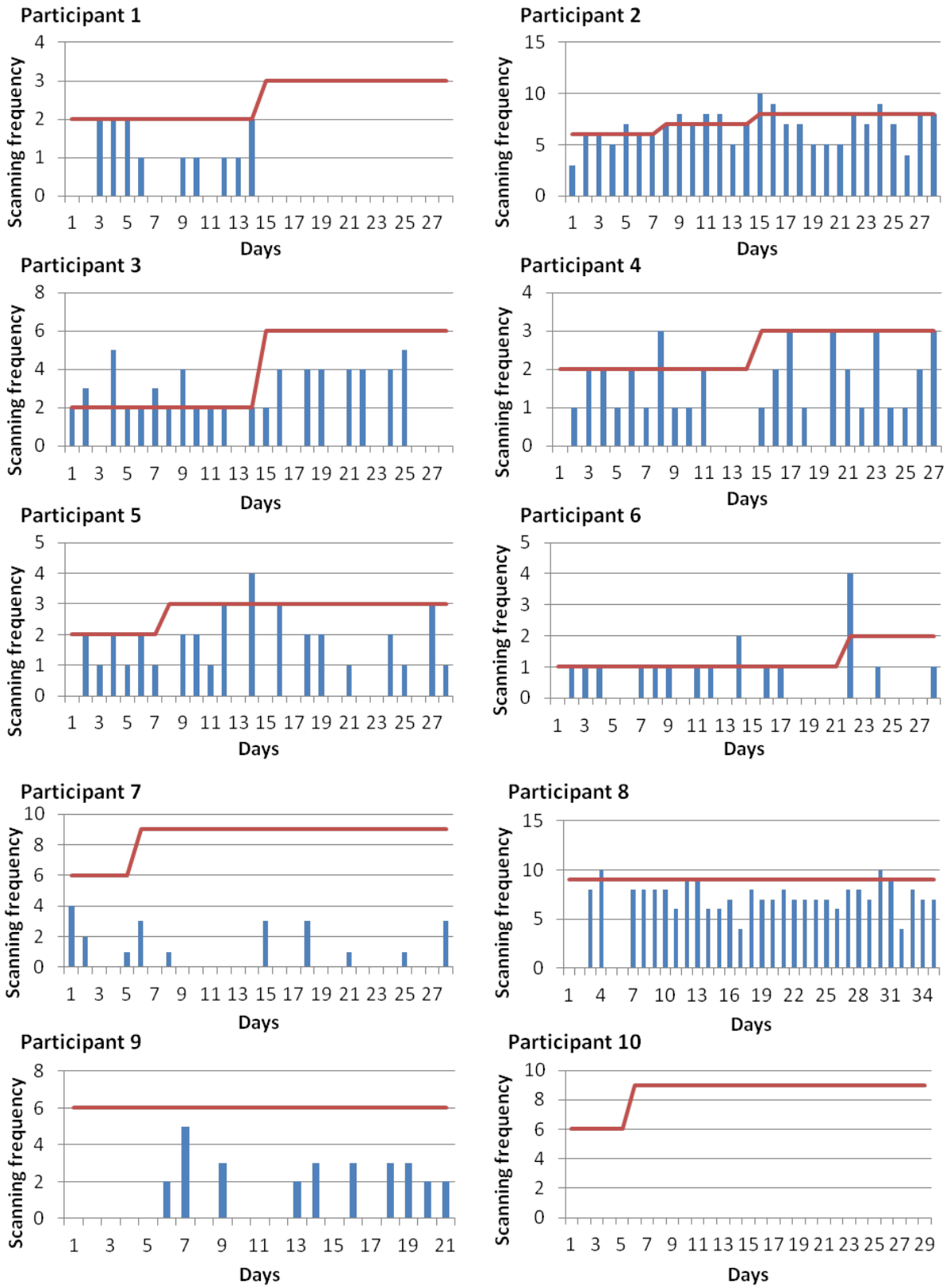


Figure 5. Individual scanning frequencies over time. Blue bars represent the total number of scans per day. The red line represents the indicated number of scans. The NA or other shoulder complaints group consisted of study participants 1-6 and the prosthesis group consisted of study participants 7-10.

Pain en confidence scores

Pain en confidence levels were registered in the feedback forms. Compliance was over 50% in all participants that used the app, but none of the participants reached the instructed daily completion. Figure 6 shows to what extent the frequency of filling in the feedback form matched with the instruction of filling it in daily.

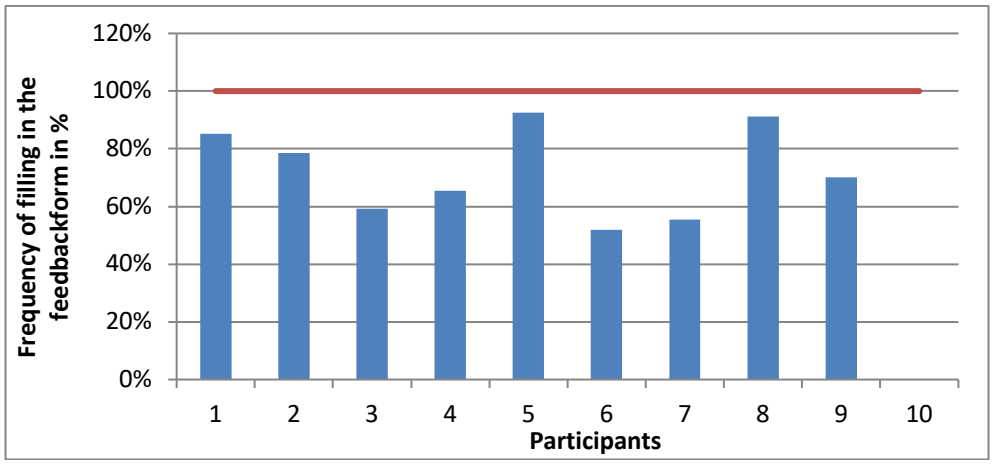


Figure 6. Compliance of filling in the feedback form. Blue bars represent the frequency of filling in the feedback form. The red line represents the instructed frequency of filling in the feedback form. The NA or other shoulder complaints group consisted of study participants 1-6 and the prosthesis group consisted of study participants 7-10.

Participants with NA or other shoulder complaints were asked to rate their pain and confidence during the day and confidence when using the affected arm. Prosthesis wearers reported their pain scores when doing their exercises and general confidence scores. The individual scores of most participants were very unstable over time. Figure 7 shows the average scores of both groups per day. For both groups the trendlines show hardly any increase or decrease in pain and confidence levels. For participants with NA or other shoulder complaints pain gradually decreased over time with a gradient of -0,011 and confidence gradually increased with gradients of 0,0231 and 0,0075. For prosthesis wearers pain decreased with a gradient of -0,0004 and confidence increased with a gradient of 0,0187.

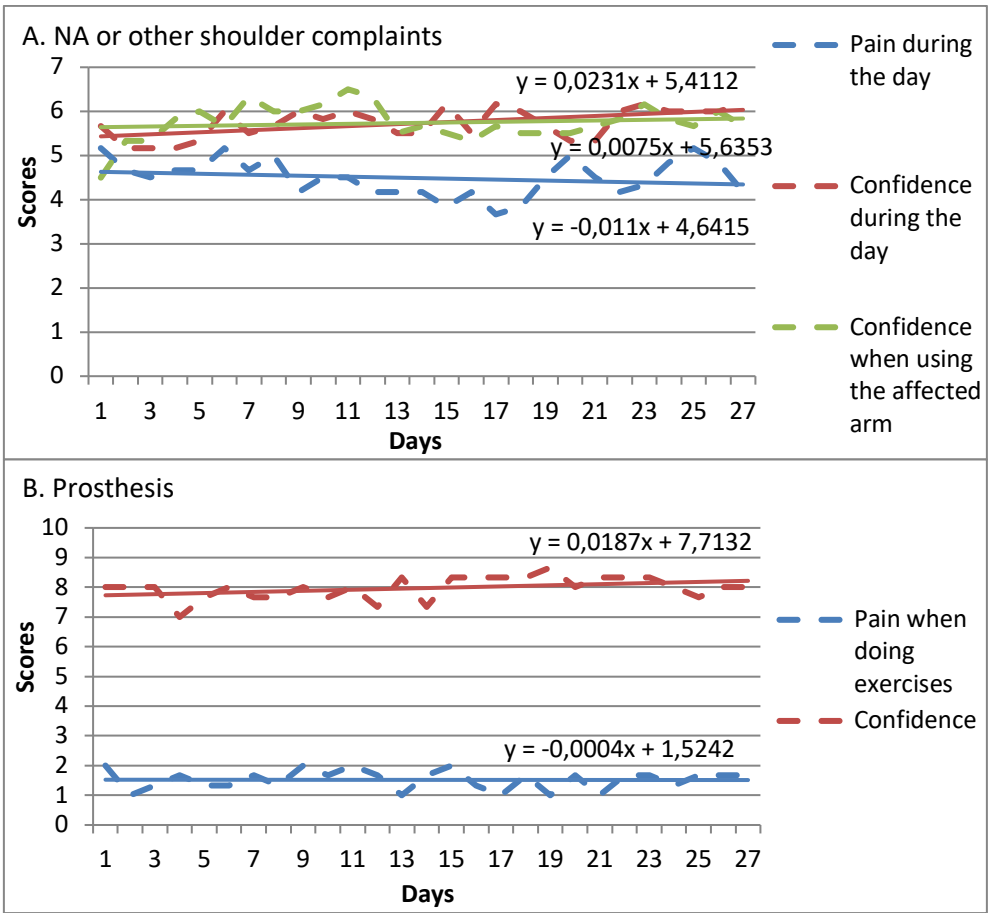


Figure 7. Pain and confidence scores over time. The dashed lines are the average scores and trendlines are added as well. A. Participants with neuralgic amyotrophy or other shoulder complaints N=6. B. Wearers of a leg prosthesis. N=3. NA= neuralgic amyotrophy

Correlations

In table 3 the correlation coefficients between the change in self-efficacy, system usability, overall grades and frequency of use are shown. There was a significant correlation between system usability and overall grade (p=0,038), but all other correlations showed no significant relations.

	Self-efficacy change	System usability	Overall grade	Frequency of use
Self-efficacy change		-0,15 (p=0,7)	-0,007 (p=0,985)	0,424 (p=0,223)
System usability			0,771 (p=0,015)*	0,103 (p=0,792)
Overall grade				-0,308 (p=0,42)
Frequency of use				

*Table 3. Correlation coefficients for the relation between the different measurements. * = correlation is significant at the 0,05 level*

Qualitative results

Ten participants and six physiotherapists were interviewed. The most important findings are discussed here and identified barriers and facilitators and positive and negative effects from the participant interviews are presented in table 4. Background information on participants is attached in Appendix D and proposed improvements for a future version of the system are listed in Appendix E.

General attitude

Both participants and physiotherapists were positive towards the concept of sticky exercises. Only one of nine users did not prefer continuing to use the system if this was possible. This person thought advices from his therapist helped him more than the exercises, so the system had little effect for him. Two additional people expressed preference for continuation of use, but only with an improved version. All of the physiotherapists stated that they would use sticky exercises if it were to be put in practice, but one first wanted to see proof of effectiveness and positive patient experiences. Some health professionals already used parts of this solution like making videos with a smartphone, advising YouTube videos or advising patients to hang up sticky notes as reminders. They liked the idea of integrating this in one digital solution. However, some factors would have to be altered before they wanted to use it on a large scale. A major problem for participants was that they could only watch the videos on fixed locations. Some wanted to do exercises on different locations within their homes, but also outside their homes like at work. We instructed participants to attach NFC tags on the wall in on instructed locations, but five participants placed the tags on a platform as opposed to attaching them and two more participants did both. Moreover, five participants did not place the tags on the instructed locations, because they did not always carry their smartphone with them, there was not a good place to hang it in the indicated location or they wanted to do the exercise on varying locations like outside. Suggested solutions were to make it possible to take the tags to different locations or to watch the video without scanning a tag. None of the participants had problems with the tags hanging in plain sight or reported privacy concerns, but for one participant privacy was a key factor for participation due to religious reasons. The therapists assumed privacy was well ensured as well, but they did not really look into that. One therapist expected problems with the tags hanging in plain sight for some patients. Overall grades from participants are presented with the system usability scores. The mean overall grade from physiotherapists was 7,3 (±0,56).

Instruction videos

Participants perceived the instructional videos as useful since they showed them how to correctly do their exercises. Consequently, the majority reported that the quality of their exercises improved. Three participants, two provided with personal videos and one with standard videos, expressed their preference for standard video's. They felt that standard videos are more clear and professional, disliked watching him/herself on video or said that standard videos show the correct way of doing the exercise as opposed to a personal movie. One person explained:

"I would benefit more from seeing how it is supposed to be carried out than from seeing myself and knowing that that is not the right way to walk" (interview 8).

Contrastingly, another participant who had personal movies preferred personal videos. He stated:

"It really has to be your own video, because then you can see your own body and how it is moving" (interview 3).

One of the therapists working with standard videos preferred standard videos because of too little added value relative to extra time investment. Another thought standard videos are fine, but new videos should be recorded to create more variation. In contrast, one preferred a combination of standard and personal videos. One physiotherapist who worked with personal videos preferred this over standard videos.

Frequency of use

Participants said the visual reminders reminded them to do their exercises, so multiple participants felt like they exercised more often. Together with the improved quality of the exercises due to the videos this in turn lead to a better and accelerated rehabilitation process according to some. Only one participant reported a negative effect which was mental pressure, but only in the beginning. Two participants claimed to have watched the videos continuously, but five participants said that when they knew how to do the exercises they stopped watching. However, the effect of the visual reminders remained. A participant said:

"The last week or two I did not scan the tags every time, but I did see them and that is something positive" (interview 1).

In the frequency of use data we did not see a decline in scanning frequency which means people kept scanning the tags, but stopped watching the videos after a while.

Pain and confidence scores

Participants tried to fill in the feedback forms daily, but sometimes they forgot or were too late. This is in line with the compliance data from the application. However, only two participants said the data was discussed with their therapist. Some thought this was a point for improvement. All therapists admitted to not discussing pain and confidence scores from the application. Prosthesis therapists did not know how to access this and were not focused on it, but would do it in the future because they acknowledged the importance. Two therapists wanted to monitor exercise frequency as well. The NA or other shoulder complaints physiotherapists did briefly look at the digital portal, but stopped doing this, because of the low added value relative to the time investment. One of them did not see the value of pain and confidence scores without comments and did not feel the need to check exercise frequencies. The other therapist explained that monitoring patients outside sessions cost too much time, but would look at it during a session together with a patient in the future. Complications that participants mentioned about the feedback form were that it was not possible to fill in the questions from the day before, the phrasing was unclear, there was no room for comments and there was no dosage field for the medication.

Usability and time investment

Due to increased frequency of exercising participants said rehabilitating with sticky exercises cost more time, but none of the participants thought the system itself was time consuming. All participants found it easy to use except for one who found it a little confusing on the first day. This was confirmed by the system usability scores. Before the start of this study physiotherapists anticipated that the system would be too time consuming, so a researcher assisted them. However, a key factor for physiotherapists was that in the future the system must be very easy to use and cost as little time as possible for them. All physiotherapists thought patients would be capable of installing the application from the app store themselves. Four therapists opted to provide them with written instructions, one suggested to appoint one responsible therapist for guidance of patients and one suggested a demo or instruction within the application. Physiotherapists said they would be willing to introduce sticky exercises during an intake session, but in the following sessions they would want to upload personal videos with just one click and activate a video by only putting a checkmark in place. All steps should be executable during the session. 2 therapists suggested coupling with the Electronic Patient Files. According to most therapists the application is not eligible for every patient, for example not for patients that do not want to watch videos, patients that are not digitally grounded or patients that require a different approach and where sticky exercises could even lead to dissatisfactory outcomes like hyper focus.

Facilitators	Positive effects
Reminding the user to do their exercises s	Increased frequency of performing the exercises
Incentive for performing exercises more often	Improved quality of home-exercises
Incentive for immediately doing an exercise after seeing the visual reminder	Having a daily ritual
Instructional video show how to perform the exercise in the right manner/ help with remembering the instructions	Constant awareness of the rehabilitation, not only during sessions with a physiotherapist
Videos show affected body parts from an angle that is normally not possible	Improved self-confidence
Fun using the system	Improved quality of moving/walking
Easy use of the system and fast scanning	Improved rehabilitation process
Easy and not time consuming feedback forms	Accelerated rehabilitation process
Insight in the frequency of performing the exercises	Progression of the rehabilitation even during periods were users are on a break from physiotherapy sessions
Insight in pain and confidence levels	Happy social environment because of the effects of the system
A push notification is a reminder to fill in the feedback form	
Barriers	**Negative effects**
Self-recorded videos do not show much and the instructions are rather boring and difficult to hear	Mental pressure because of the system
Requirement of always carrying a smartphone which not all users do	
NFC tags are fixed on the wall preventing the possibility of doing the exercises on a different location	
Videos, reminders and pain registration are not necessary for performing home exercises	
Technical problems with the smartphone application	
High battery consumption of the smartphone application	
Displeasure to see oneself on a video	

Table 4. Facilitators, barriers, positive effects and negative effects of the intervention presented according to the framework of Gagnon et al. and the Donabedian Framework for Quality of care (36, 37).

Discussion

Principle findings

In this exploratory study, nine people successfully used a digital solution aimed at increasing the frequency and quality of home exercises. Despite the short study period of four weeks, in the NA or other shoulder complaints group the sticky exercise system has already shown to cause an effect on self-efficacy. Usability of the system was highly acceptable. Users were generally very positive about the intervention and stated that it positively affected their recovery. We identified barriers, facilitators and effects as well as suggestions for improvement. In only four weeks it was unclear if pain and confidence levels changed.

Other studies

Similar to this study other studies have also proven the feasibility of digital interventions in physiotherapy. For example in the Dunphy et al. where they tested a web-based tool with instruction videos and progress logs to support knee rehabilitation(22). They did not asses clinical outcomes. In the pilot study of only three weeks by Stutz et al. they also found high system usability for their smartphone application with exercises instructions and monitoring of training compliance and progress (SUS score of 88)(25). As opposed to our study they did find excellent compliance of usage. Other studies assessing digital tools with similar features as sticky exercises showed positive clinical outcomes, for example improved physical function(38-40). In our study we did not measure adherence or clinical outcomes, but prior research showed that self-efficacy is related to physiotherapy adherence and clinical outcomes(4, 7, 13-17). Although the above mentioned tools are similar to sticky exercises, none of them contained visual reminders, the possibility to add personal videos or NFC technology. Therefore, sticky exercises is the first application with this unique combination of features and possibilities for personalisation.

Discussion of the results

In line with our aim to increase adherence and exercise quality, participants reported often that they were reminded by the visual reminders and videos were useful as they showed how to do the exercise in the right manner which lead to an increased quality and frequency of doing exercises. This in turn lead to better or accelerated rehabilitation according to some participants. This shows great potential for the sticky exercise system. The perceived high exercise frequency was not supported by the scanning frequencies, but this could be because users could do exercises without scanning or the other way around and the minimum indicated frequency in the application was once a day while sometimes a therapist instructed to do an exercise less frequent than once a day.

Our results show that there is a lot of variation between participants. For example, there was a difference in self-efficacy in the NA or other shoulder complaints group, but not in the prosthesis group illustrating that it does not work the same for every patient group. It might be that prosthesis wearers do benefit from the system, but only when using it for a longer period of time. Also there was a lot of variation in individual scanning frequencies which could be explained by personal preferences. In the interviews some participants were more positive about the reminders and some more about the videos. Therefore participants that did not scan as often might benefit from the

reminders, but less from the videos. The advantage of the sticky exercises system is that personal preferences can be taken into account to offer a personalized treatment. In the interviews it became apparent that preferences also changed over time. Participants explained that they did not watch the videos anymore after some time, but the effect of the visual reminders remained. The combination of features in the sticky exercises was therefore perceived as positive. Although we expected to see a decline in scanning frequency over time as a consequence, this was not the case, because participants still felt the urge to scan even though they did not watch the video anymore.

The physiotherapists also had varying preferences when it comes to the feedback forms. NA or other shoulder complaints physiotherapists were not keen about the current way of monitoring, but might use it if changes are made. It must be taken into account that in their regular care they did not use patient diaries yet, so monitoring pain and confidence was not yet imbedded in their daily routine. If in the future they would change their care process though, monitoring could improve patient care. Prosthesis therapists did not monitor their patients often, but they did think monitoring pain and confidence is very important and therefore thought this feature of sticky exercises is an important asset that they would definitely use in the future. With the sticky exercises system it is possible to activate or deactivate feedback forms depending on preferences of the physiotherapist or patient which is another opportunity for personalisation.

The mean system usability score of 80,8 corresponds to the top 10% of scores or an A grade according to Sauro and Lewis and good acceptability, good to excellent rating or a B grade according to Bangor et al.(41, 42). Participants found it easy to use and it did not cost them much time. Physiotherapists had some concerns about time investment, so an improved version of the application must be an easy, not time consuming system that therapists could use during the session and where the patients can to do most steps themselves. However, they were very positive towards the concept of sticky exercises and wanted to use it in general practice, indicating potential for the future. Also all but one of the participants would have like to continue using the system if this were possible.

Limitations

This study holds some limitations. Since this was a pilot study the sample size was rather small and the follow-up time short. However, we did already see results in four weeks in our group of participants. Secondly the participants were not randomly assigned to the intervention group or the control group, but based on their type of smartphone, and we observed multiple declines for participation. Both could lead to selection bias. Furthermore not all prosthesis physiotherapists were well instructed or had access to the digital portals, so they could not take the initiative for monitoring patients. Despite our efforts to plan the final consultation after four weeks, sometimes this was not possible resulting in a shorter or longer intervention period. Lastly, the application did not work during one weekend due to technical problems, so unfortunately patients could not use it in that period which could have lead to underestimation of scanning frequencies and compliance of filling in the feedback form.

Recommendations

The results show potential for further development. We recommend to first develop an improved version of the system taking into account the suggested improvements and barriers for usage. Since this pilot study was only short and with a small amount of subjects, we propose a large follow-up study that studies the effect on self-efficacy on the longer term, but also on objective rehabilitation effects like pain levels, pain medication, number of therapy sessions, quality of moving, recurrence of complaints and cost effectiveness. We think the concept of sticky exercises can be very beneficial in improving rehabilitation care.

Conclusion

Using the sticky exercises system for four weeks lead to an increased self-efficacy in patients with NA or other shoulder complaints, but not in prosthesis wearers. Furthermore, the usability of the system was highly acceptable. Users were generally very positive about the intervention and stated that it positively affected their recovery. It is unclear whether the system lead to a change in pain or confidence since we only studied the effect after four weeks.

References

1. Bassett S. The assessment of patient adherence to physiotherapy rehabilitation. New Zealand Journal of Physiotherapy. 2003;31(2):60-6.
2. Sluijs EM, Kok GJ, van der Zee J. Correlates of exercise compliance in physical therapy. Physical therapy. 1993;73(11):771-82; discussion 83-6.
3. Sluijs EM. Patient education in physical therapy. NIVEL, Utrecht. 1991.
4. Engstrom LO, Oberg B. Patient adherence in an individualized rehabilitation programme: a clinical follow-up. Scandinavian journal of public health. 2005;33(1):11-8.
5. Groth GN, Wilder DM, Leroy Young V. The Impact of Cormpliance on the Rehabilitation of Patients with Mallet Finger Injuries. Journal of Hand Therapy. 1994;7(1):21-4.
6. Lyngcoln A, Taylor N, Pizzari T, Baskus K. The relationship between adherence to hand therapy and short-term outcome after distal radius fracture. Journal of hand therapy : official journal of the American Society of Hand Therapists. 2005;18(1):2-8; quiz 9.
7. Brewer B, Vanraalte J, Cornelius A, Petitpas A, H. Sklar J, H. Pohlman M, et al. Psychological factors, rehabilitation adherence, and rehabilitation outcome after anterior cruciate ligament reconstruction2000. 20-37 p.
8. Kerssens JJ. Effect van therapietrouw in de fysiotherapie. NIVEL. 1998.
9. Forkan R, Pumper B, Smyth N, Wirkkala H, Ciol MA, Shumway-Cook A. Exercise adherence following physical therapy intervention in older adults with impaired balance. Physical therapy. 2006;86(3):401-10.
10. Akinsola MK, Awofala AOA. Effect of personalization of instruction on students' achievement and self-efficacy in mathematics word problems. International Journal of Mathematical Education in Science and Technology. 2009;40(3):389-404.
11. Ilgen D, Fisher C, Susan M. Consequences of individual feedback on behavior in organizations1979. 349-71 p.
12. Knoblich G, Flach R. Predicting the effects of actions: interactions of perception and action. Psychol Sci. 2001;12(6):467-72.
13. Chen CY, Neufeld PS, Feely CA, Skinner CS. Factors influencing compliance with home exercise programs among patients with upper-extremity impairment. The American journal of occupational therapy : official publication of the American Occupational Therapy Association. 1999;53(2):171-80.
14. Neupert SD, Lachman ME, Whitbourne SB. Exercise Self-Efficacy and Control Beliefs Predict Exercise Behavior After an Exercise Intervention for Older Adults. Journal of aging and physical activity. 2009;17(1):1-16.
15. Woodgate J, Brawley LR, Weston ZJ. Maintenance Cardiac Rehabilitation Exercise Adherence: Effects of Task and Self-Regulatory Self-Efficacy. Journal of Applied Social Psychology. 2005;35(1):183-222.
16. Jack K, McLean SM, Moffett JK, Gardiner E. Barriers to treatment adherence in physiotherapy outpatient clinics: A systematic review. Manual Therapy. 2010;15(3-2):220-8.
17. Bassett SF, Prapavessis H. A test of an adherence-enhancing adjunct to physiotherapy steeped in the protection motivation theory. Physiotherapy theory and practice. 2011;27(5):360-72.
18. Stawarz K, Cox AL, Blandford A. Beyond self-tracking and reminders: designing smartphone apps that support habit formation. Proceedings of the 2015 Conference of Human Factors in Computing Systems. 2015:2653-62.
19. Hamine S, Gerth-Guyette E, Faulx D, Green BB, Ginsburg AS. Impact of mHealth chronic disease management on treatment adherence and patient outcomes: a systematic review. Journal of medical Internet research. 2015;17(2):e52.
20. Linn AJ, Vervloet M, van Dijk L, Smit EG, Van Weert JC. Effects of eHealth interventions on medication adherence: a systematic review of the literature. Journal of medical Internet research. 2011;13(4):e103.

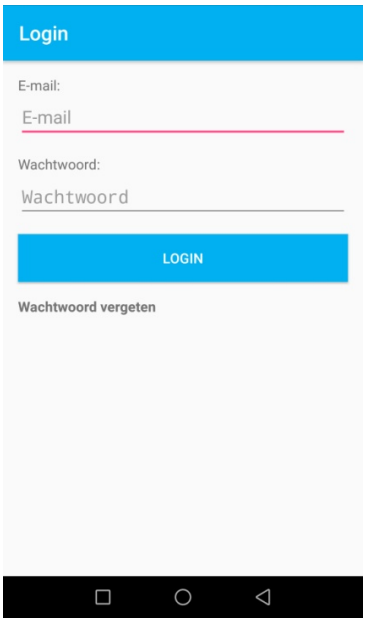
21. Barello S, Triberti S, Graffigna G, Libreri C, Serino S, Hibbard J, et al. eHealth for Patient Engagement: A Systematic Review. Frontiers in psychology. 2015;6:2013.
22. Dunphy E, Hamilton FL, Spasic I, Button K. Acceptability of a digital health intervention alongside physiotherapy to support patients following anterior cruciate ligament reconstruction. BMC musculoskeletal disorders. 2017;18(1):471.
23. Friedrich M, Gittler G, Halberstadt Y, Cermak T, Heiller I. Combined exercise and motivation program: effect on the compliance and level of disability of patients with chronic low back pain: a randomized controlled trial. Archives of physical medicine and rehabilitation. 1998;79(5):475-87.
24. Lambert TE, Harvey LA, Avdalis C, Chen LW, Jeyalingam S, Pratt CA, et al. An app with remote support achieves better adherence to home exercise programs than paper handouts in people with musculoskeletal conditions: a randomised trial. Journal of physiotherapy. 2017;63(3):161-7.
25. Stutz T, Emsenhuber G, Huber D, Domhardt M, Tiefengrabner M, Oostingh GJ, et al. Mobile Phone-Supported Physiotherapy for Frozen Shoulder: Feasibility Assessment Based on a Usability Study. JMIR rehabilitation and assistive technologies. 2017;4(2):e6.
26. van Alfen N, van Engelen BG. Neuralgische amyotrofie: Een praktische update. Tijdschrift voor Neurologie en Neurochirurgie. 2007;108(4):161-9.
27. Van Eijk JJ, Groothuis JT, Van Alfen N. Neuralgic amyotrophy: An update on diagnosis, pathophysiology, and treatment. Muscle & nerve. 2016;53(3):337-50.
28. Ijspeert J, Janssen RM, Murgia A, Pisters MF, Cup EH, Groothuis JT, et al. Efficacy of a combined physical and occupational therapy intervention in patients with subacute neuralgic amyotrophy: a pilot study. NeuroRehabilitation. 2013;33(4):657-65.
29. Leijendekkers RA, van Hinte G, Nijhuis-van der Sanden MW, Staal JB. Gait rehabilitation for a patient with an osseointegrated prosthesis following transfemoral amputation. Physiotherapy theory and practice. 2017;33(2):147-61.
30. Abdo WF, Bloem BR, Eijk JJ, Geurts AC, van Alfen N, van de Warrenburg BP. Atypical dystonic shoulder movements following neuralgic amyotrophy. Movement disorders : official journal of the Movement Disorder Society. 2009;24(2):293-6.
31. van Alfen N. Clinical and pathophysiological concepts of neuralgic amyotrophy. Nature reviews Neurology. 2011;7(6):315-22.
32. van Alfen N, van Engelen BG. The clinical spectrum of neuralgic amyotrophy in 246 cases. Brain : a journal of neurology. 2006;129(Pt 2):438-50.
33. van Alfen N, van Eijk JJ, Ennik T, Flynn SO, Nobacht IE, Groothuis JT, et al. Incidence of neuralgic amyotrophy (Parsonage Turner syndrome) in a primary care setting--a prospective cohort study. PloS one. 2015;10(5):e0128361.
34. Frolke JP, Leijendekkers RA, van de Meent H. Osseointegrated prosthesis for patients with an amputation : Multidisciplinary team approach in the Netherlands. Der Unfallchirurg. 2017;120(4):293-9.
35. Fortington LV, Rommers GM, Postema K, Netten JJv, Geertzen JH, Dijkstra PU. Lower limb amputation in Northern Netherlands: Unchanged incidence from 1991–1992 to 2003–2004. Prosthetics and orthotics international. 2013;37(4):305-10.
36. Gagnon MP, Desmartis M, Labrecque M, Car J, Pagliari C, Pluye P, et al. Systematic review of factors influencing the adoption of information and communication technologies by healthcare professionals. Journal of medical systems. 2012;36(1):241-77.
37. Donabedian A. The quality of care. How can it be assessed? Jama. 1988;260(12):1743-8.
38. Bennell KL, Nelligan R, Dobson F, Rini C, Keefe F, Kasza J, et al. Effectiveness of an Internet-Delivered Exercise and Pain-Coping Skills Training Intervention for Persons With Chronic Knee Pain: A Randomized Trial. Annals of internal medicine. 2017;166(7):453-62.
39. Bossen D, Veenhof C, Van Beek KE, Spreeuwenberg PM, Dekker J, De Bakker DH. Effectiveness of a web-based physical activity intervention in patients with knee and/or hip osteoarthritis: randomized controlled trial. Journal of medical Internet research. 2013;15(11):e257.

40. van Het Reve E, Silveira P, Daniel F, Casati F, de Bruin ED. Tablet-based strength-balance training to motivate and improve adherence to exercise in independently living older people: part 2 of a phase II preclinical exploratory trial. Journal of medical Internet research. 2014;16(6):e159.
41. Sauro J, Lewis JR. Quantifying the user experience: Practical statistics for user research: Morgan Kaufmann; 2012. 312 p.
42. Bangor A, Kortum P, Miller J. Determining what individual SUS scores mean: adding an adjective rating scale. J Usability Studies. 2009;4(3):114-23.

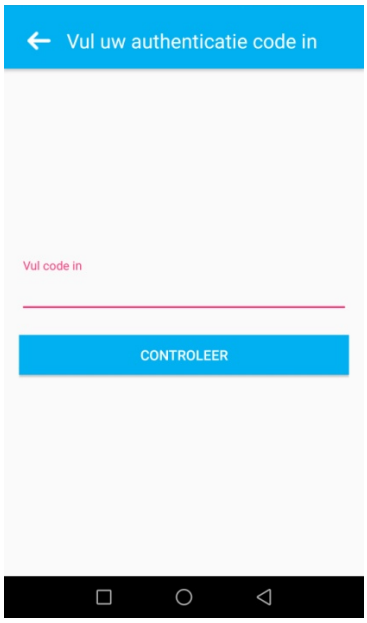
Appendix A

Screenshots of the smartphone application and the digital portal for healthcare professionals

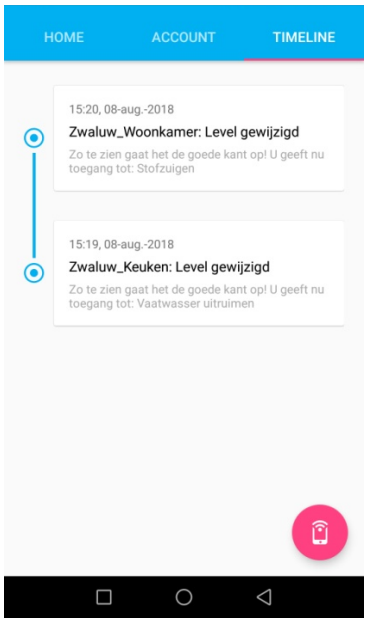
Smartphone application for patients



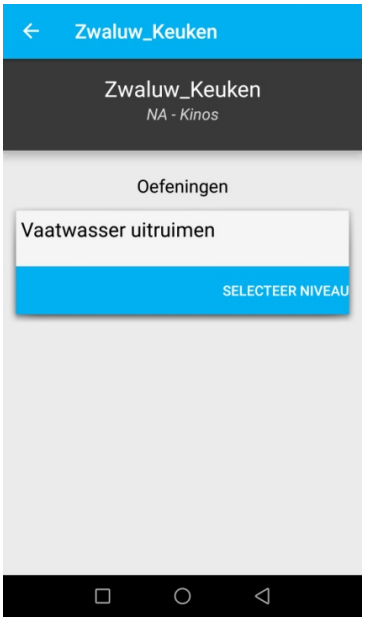
Login screen with username and password



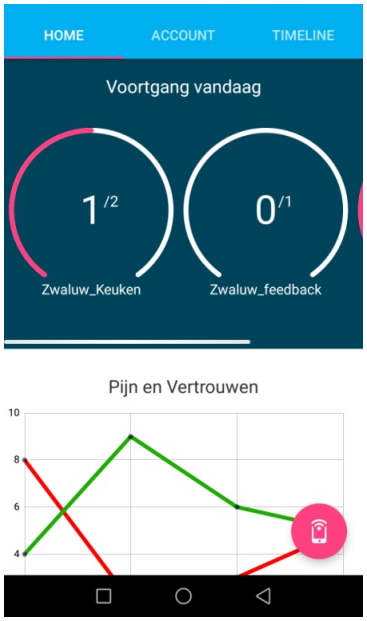
Confirm identity with the authenticator code



Timeline of assigned exercises



Selecting the video after scanning a tag



Scanning frequency

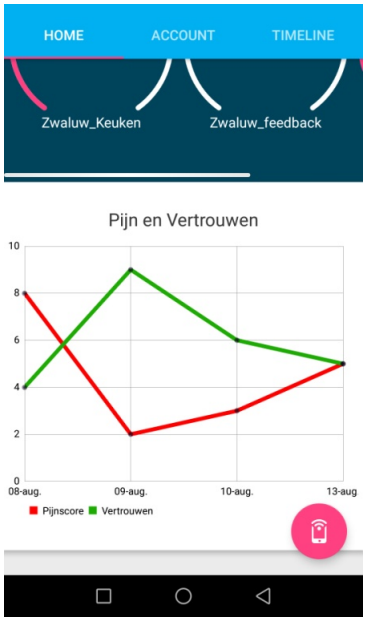
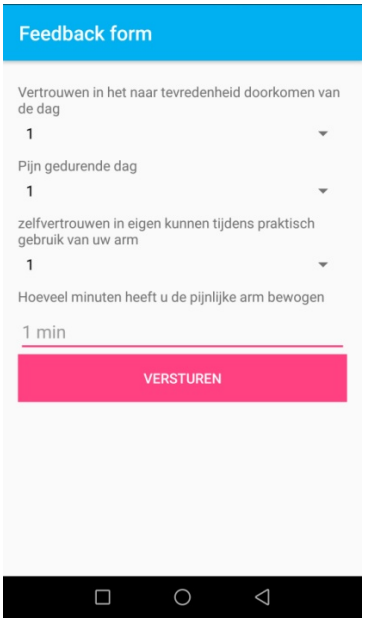


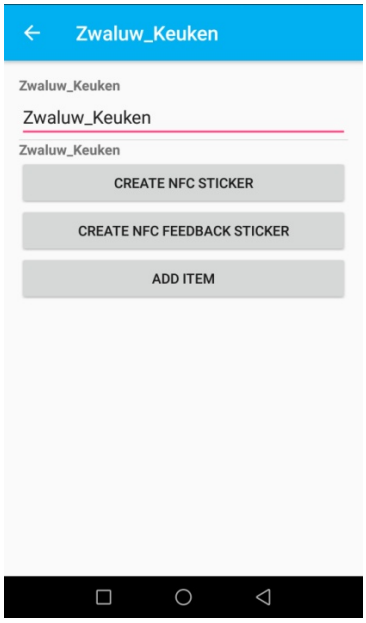
Chart of pain and confidence levels

Feedback form prosthesis



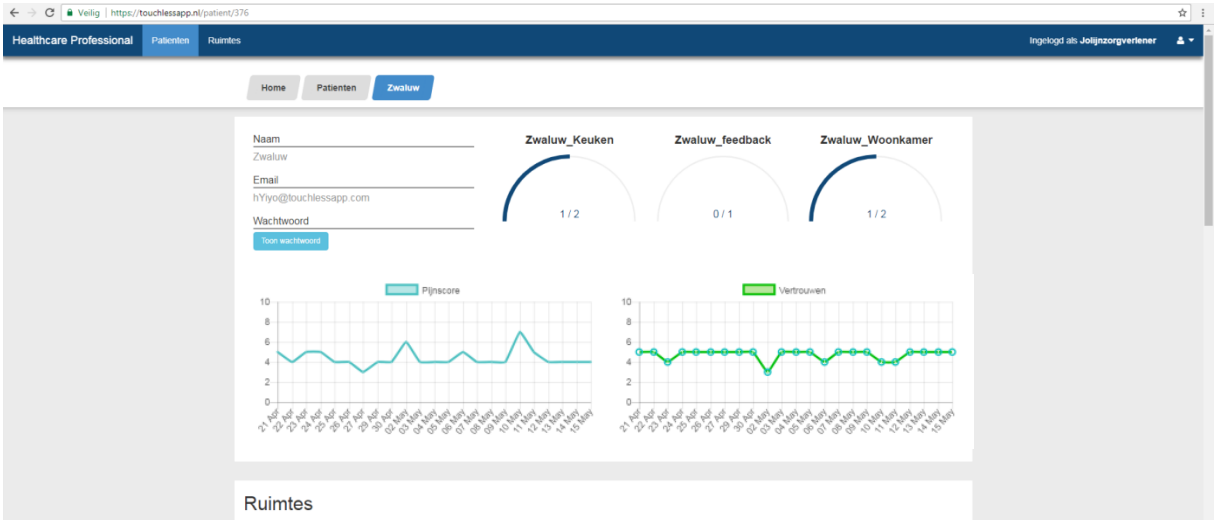
Feedback form NA or other shoulder complaints

Back-end smartphone application for programming NFC tags

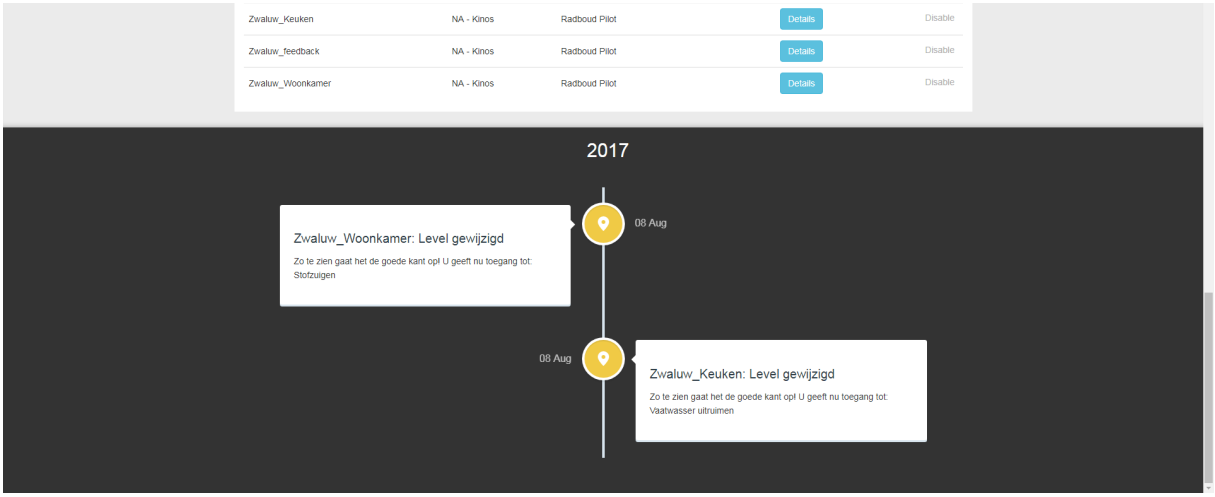


Coupling an NFC tag to an exercise

Digital portal for health professionals



Monitoring the scanning frequency and pain and confidence levels of a patient

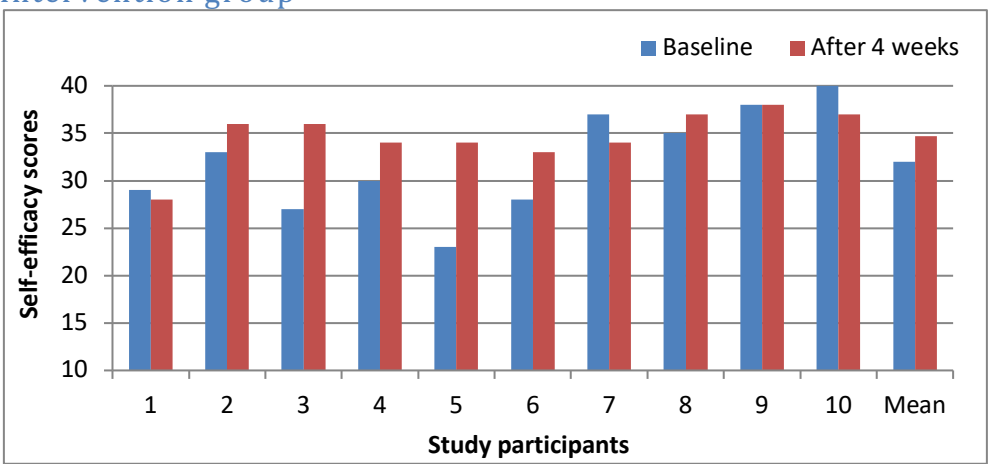


Timeline of assigned exercises

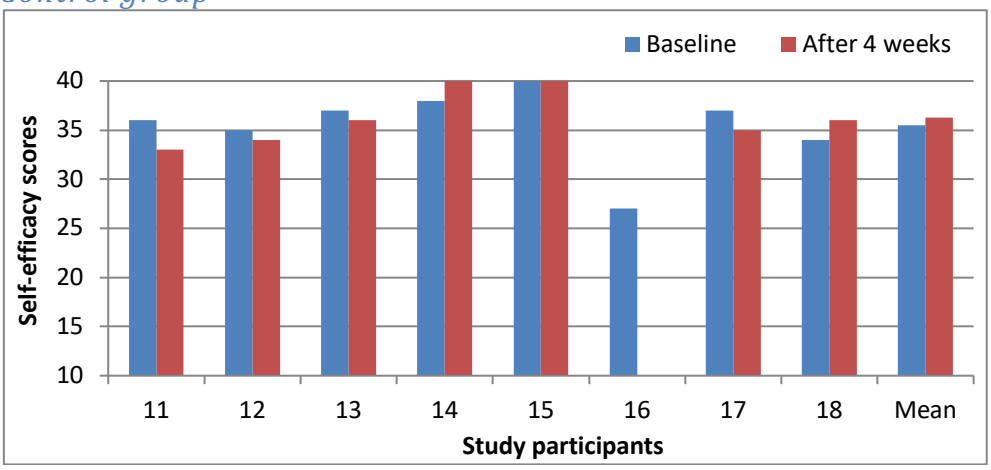
Appendix B

Individual self-efficacy scores

Intervention group



Control group



Appendix C

Aspects that affected confidence and insecurity in the rehabilitation

	Self-efficacy at baseline		Self-efficacy after 4 weeks	
Participant	**Aspects that affected confidence in the rehabilitation.**	**Aspects that affected insecurity in the rehabilitation.**	**Aspects that affected confidence in the rehabilitation.**	**Aspects that affected insecurity in the rehabilitation.**
1	Expertise.	Insecurity if everything is going to be okay.	Expertise.	-
2	They prevent recurrence of complaints.	There are little practical exercises.	Behaviour modification by occupational therapist affects recovery.	Afraid that pain in shoulder will come back, but have not had any problems for 4-5 months.
3	-	-	-	-
4	Because during the rehabilitation I am made aware of the wrong position of my shoulder and I have to pay attention to the right position.	-	Learned to use my shoulder in the right manner.	-
5	The people that help me are experienced. The exercises that I have to do actually help.	Little self-esteem which is why I am afraid to do the exercises wrong.	I feel like it is improving and that gives me confidence.	If I get a lot of pain after doing exercises I can be very insecure.
6	Learn new ways to move.	-	I learned to deal with the pain and to move in the right manner. For example with doing the dishes and hanging up clothes. I can do this now with hardly any pain.	I constantly have to think about my shoulder. In the gym, with walking, with grocery shopping. I constantly have to take it into account and I have to listen to my shoulder.
7	-	-	-	-
8	Seeing other patients rehabilitating.	-	Therapy (smartphone application).	-

9	Tips and tricks by which walking improves and is more smoothly again.	-	Persistence.	Health is sometimes a limiting factor.
10	Facilities and knowledge is provided.	-	Teach how to move.	-
11	The rehabilitation especially shows me and makes me accept what I can and cannot do.	-	I have confidence in the rehabilitation, because I think the therapists at KINOS are well informed about NA. Because of that I think I am in the right place at KINOS.	A major insecure aspect is that nobody can tell me to what extent the damage from the NA will recover. It is still hard to accept this and to have to await. You learn not to look at the things that you cannot do anymore, but to the things that you can do, but in my opinion there are very little things you can do if you can hardly use your arm/shoulder.
12	There is being taught along and looked for solutions.	-	I can do more and more en get more grip on the situation. More control over the movements of my shoulder.	The final results are uncertain.
13	I notice improvement of my possibilities.	-	-	-
14	Treatment in Radboudumc.	Negative things said by others whereas I am always positive.	Physiotherapists make a great effort. They really have my back.	-
15	My leg feels good.	That there has been tinkered with my bone.	My leg (stump) feels very good, very solid.	-
16	-	-	-	-

17	The help that will help me along.	Pain.	Motivate where this is possible. And show things that I did not think were possible (bike riding and the way of walking).	-
18	Always stay cheerfully.	If my other leg will not abandon me.	I have only been rehabilitating for 6 weeks and I can already do so much with my new leg which was never the case with the socket prosthesis, so I am convinced that it will happen really fast that I can walk freely or with 1 stick if necessary in the future.	-

Study participants 1-10 are in the intervention group where 1-6 are patients with NA or other shoulder complaints and 7-10 are prosthesis wearers. Study participants 11-18 are in the control group where 11-13 are participants with NA or other shoulder complaints and 14-18 are prosthesis wearers.

Appendix D

Background information on participants

Six participants had never used an e-health application prior to the study. Two had used it before, one for assistance in losing weight and the other for communication with a health coach from a hospital. Seven of ten participants expressed a positive attitude towards the care provided by the rehabilitation department or clinic whereas one participant expected and preferred a different rehabilitation approach with more exercises for strengthening muscles or massages.

Appendix D

Suggested improvements by patients

Improvements for the system development	Improvements in the healthcare process
Give the user the choice to watch the video or not instead of automatically showing it every time	Discuss scanning frequency with patient during the therapy session
Make it possible to use the tags on different locations	Discus pain and confidence scores with patient during the therapy session
Make it possible to watch the video without scanning the tag	Physiotherapist monitors patients remotely and patients only have to visit the practice if this is necessary
Provide textual instructions for the exercises for situations in which the user cannot watch the video (e.g. in the bus or at school)	Use standard professional videos instead of self-recorded videos
Make it possible to pause and stop the videos and save them on a computer	Divide the videos into smaller parts so the user can select the relevant part
Send push messages when the prescribed exercises are not performed	Explain what pain scores mean
Send push messages about the feedback form in the evening instead of in the morning	Explain with which side of the smartphone the tags have to be scanned
In the feedback form jump over to the next day at 4 am instead of at 12 pm	Explain how to turn on the sound with the videos
Make it possible to fill in the feedback form of the day before	
Make sure the feedback form starts automatically at the first question instead of the third	
Do not cover part of the feedback form by the keyboard	
Add the possibility to give comments with the pain and confidence scores in the feedback form	
Complete the medication list in the feedback form	
Add an extra dosage field to the medication questions in the feedback form	
Alter the phrasing of the questions in the feedback form to make them clearer	
Improve the design of the app and the NFC tags: create a unified corporate design both in the app and the NFC tags	
Improve the design of the NFC tags: add text and use a more realistic illustration	
Improve the design of the NFC tags: make a clear distinction between the different locations that are depicted	

Get movement advices via the application	

Suggested improvements by healthcare professionals

Improvements for the system development	Improvements in the healthcare process
Make the application suitable for both Android and Apple smartphones	Add both standard and personal videos
Make it easy for a patients to install the application themselves from the app store	Create more variation in the standard videos
Make it possible for patients to upload videos as well	Make patient accounts without codenames so their data is immediately recognizable for a physiotherapist
Use the videos in the application as a database and do not show them automatically every time a patient performs an exercise	Do not use pain diaries on paper anymore, only digital registrations
Add an information page about the institution or department	Discus deviating pain and confidence scores with patient during the therapy session if necessary
Add a competition element and interaction/communication with other users	Use pain and confidence data for research on for example prediction of pain
Make sure that using the digital portal is very easy and requires minimal time for physiotherapists	Provide instructions for installation and use of the application. Can be written instructions, verbal instructions or a demo/instruction within the application
Make it possible to use the digital portal during a session (where there is not always a computer within reach)	
Link the digital portal for health professionals to the electronic patient files	
Add a comment section to the pain and confidence scores	
Show the scanning frequency over a longer period, not only over 1 day	
Do not adhere stickers to the NFC tags, but use tags with fixed illustrations	
Find a solution for patients that do not like the tags hanging in plain sight	
Provide instructions for installation and use of the application. Can be written instructions, verbal instructions or a demo/instruction within the application	