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EVALUATION AND DEVELOPMENT OF A DECISION SUPPORT SYSTEM FOR PATIENTS AFTER AN OPEN HEART SURGERY

Early online cardiac telerehabilitation programme

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My part of this project was to include patients in the study and to assist with the data collection. The data collection consisted of different tests with patients performed by physiotherapists. I have learned a lot, working in the hospital and it was a valuable experience next to my education. I could experience the daily practice in a hospital and how all the different disciplines work together. This thesis completed my studies at the university. At the end, I appreciate that I could take part in this project and gather all those experiences that I normally would have missed out on during my study.

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Keywords: early cardiac telerehabilitation, decision support system, eHealth.

Abstract:

A decision support system can contribute to the efficiency of eHealth in cardiac rehabilitation. This research uses the early online cardiac telerehabilitation program from the Medisch Spectrum Twente. Once every week, physiotherapists were asked to set up a training schedule for patients. The schedule was set up on the portal, supported by a fixed training schedule on paper. Besides that, the physiotherapists personalized the training schedule once every week with the use of a decision tree, e.g. to adjust the level of intensity for the exercises. A decision support system can automatically set up a training schedule for each patient. In addition, it can automatically adjust the exercises to personalize the exercises for a patient. The aim of this study was to; 1) validate the training schedule and the decision tree, and consequently, 2) to define requirements for the development of a decision support system which can automatically personalize the exercises within the training schedule per individual, as part of the early online cardiac telerehabilitation program of the Medisch Spectrum Twente.

To validate the training schedule and the decision tree, we compared two situations, 1) The fixed training schedule and the decision tree with 2) how the physiotherapists set up the training schedule. Hereafter requirements were defined for a decision support system, with the use of interviews with physiotherapists and observations in daily practice by the researcher. The requirements were evaluated and a mock-up of a decision support system was made. It is stated that the training schedule and decision tree are valid if no unsafe exercises are prescribed and when the physiotherapists are satisfied with the training schedule or decision tree.

13 patients were included to validate the training schedule. To validate the decision tree 20 patients were included of which 16 patients were analyzed. The differences which were found between the 2 situations, were mainly caused by human errors, i.e. physiotherapists who were not focused when setting up the training schedule or adjusting the levels of intensity. Regarding the training schedule in 64% of the exercises a difference was found between the fixed training schedule and the outcome of the physiotherapist. Regarding the decision tree, in 11% of the total prescribed exercises a difference was observed between the decision tree and the outcome of the physiotherapist. The main reason for these differences were the same as the training schedule. Besides that, the physiotherapists did not believe the input of the patients on the portal.

Overall, the physiotherapists were satisfied with the fixed training schedule and the decision tree. Therefore, it is assumed that the training schedule and the decision tree are valid. Moreover, the requirements had no feedback and no changes needed to be made. Furthermore, the decision support system is highly appreciated by the physiotherapists and would make their work more efficient and easier.

Further work should focus on the experiences of patients with the program. With this information the programme can be further optimized to the needs of the patients. Besides that, the possibility to expand the programme with monitoring sensors could make the program more efficient and safe for the patient. In this way, vital functions such as heart rate and blood pressure can be monitored and warnings can be given to alert the patient.

1. INTRODUCTION

Cardiovascular diseases are the main cause of death in the world. In 2012, roughly 17.5 million people died due to CVD's, representing 31% of all global deaths, 7.4 million of the global deaths were caused by coronary heart disease and 10.1 million were caused by a stroke (WHO, 2016).

Cardiac rehabilitation is of upmost importance to prevent recurrence of a cardiac event or further progression of an existing cardiac disorder by reducing unhealthy behaviour and risk factors. As defined by Dafoe et al. (2006) "cardiac rehabilitation services are comprehensive, long term programs involving medical evaluation, prescribed exercise, cardiac risk factor modification, education, and counselling".

A major element in cardiac rehabilitation programs is exercise-based treatment, other components are psychosocial support and education. Exercise-based cardiac rehabilitation is an effective treatment which reduces cardiovascular absolute mortality risk from 10.4% to 7.4% (Dalal, Doherty, & Taylor, 2015), compared to patients who did not receive exercise-based cardiac rehabilitation. Furthermore, cardiac rehabilitation reduces hospital admissions from 30.7% to 26.1% and depression-related symptoms from 22% to 13%. (Dalal, et al., 2015)

Although there is no clear consensus in literature, usually the time for the healing of the sternum (i.e. 6 weeks) is being used for the start of cardiac rehabilitation (Scalvini et al., 2009). Likewise, Medisch Spectrum Twente (MST) starts with cardiac rehabilitation after 6 weeks. During these 6 weeks, patients are asked to pick up their daily activities and get used to their life at home. A survey among 50 cardiac patients who completed the regular cardiac rehabilitation program at MST, showed that patients felt uncertain in these first weeks after discharge and did not know what they could do regarding physical activities. Patients considered the waiting time for the start of the regular cardiac rehabilitation as too extensive and the advice for structuring their daily activities after discharge insufficient (Fokkens, 2014).

Furthermore, to maximize the outcomes of cardiac rehabilitation, patients need to be as active as possible in the 6 weeks before cardiac rehabilitation (Fokkens, 2014). Early cardiac rehabilitation (start with training in the weeks before the regular cardiac rehabilitation) could have positive effects on patients' physical and psychological recovery. Early cardiac rehabilitation can result in less readmissions compared to regular cardiac rehabilitation (19.0% vs. 35.1%) and no increase and risk for post-operative complications the week after discharge (Scalvini, et al., 2009). Additionally, a higher level of daily activities could be achieved if cardiac rehabilitation starts earlier (Eder et al., 2010; Fell, Dale, & Doherty, 2016; Pack, Dudycha, Roschen, Thomas, & Squires, 2015).

With an increasing number of persons who live with CVD-related issues, it requires extra effort from patients and caregivers to manage their symptoms and prognosis (Anderson et al., 2016). As such, an increasing number of home based cardiac rehabilitation programmes are offered in the form of eHealth. These programs are offered through e.g. telephone communication, mobile phone messages and email to support, motivate and provide feedback about goal achievement and exercise adherence. Current eHealth programmes for cardiac rehabilitation contain telemonitoring, telesupport (active telesupport by healthcare providers), telecoaching (support and instruction for therapy) and telerehabilitation. The two major components for eHealth in cardiac rehabilitation are telemonitoring and telerehabilitation (Piotrowicz et al., 2016):

- Telemonitoring is defined as transferring data like symptoms (fatigue, chest pain, etc.), physiological data (heart rate, blood pressure, weight, etc.) from the patient to healthcare providers. This can be done manually or automatically, when done manually the transferred data is examined by the healthcare provider and feedback is given to patients. When it is done automatically, an intelligent system or decision support system can set an alarm when a dangerous threshold is met or support healthcare providers when a decision needs to be made.
- Telerehabilitation is defined as supervised remote cardiac rehabilitation and includes telecare and supervision of exercise training.

Telesupport and telecoaching can both be a part of telemonitoring and telerehabilitation. They can play a significant role in the utilization of telemonitoring and telerehabilitation programmes. (Piotrowicz, et al., 2016)

Reviews show that cardiac telerehabilitation based on exercises is as effective as current cardiac rehabilitation when comparing the physiological and duration improvement. These reviews concluded that exercise based cardiac rehabilitation telehealth program shows to be a safe way to deliver cardiac rehabilitation to patients at home (Huang et al., 2014; Rawstorn, Gant, Direito, Beckmann, & Maddison, 2016). To the best of our knowledge, early cardiac rehabilitation is not yet offered through eHealth, and only 2 programmes are currently in development: “PaTHway” (Filos et al., 2016) & “SMART-REHAB trial” (Yudi et al., 2016).

Using a decision support system in eHealth can further optimize the time and effort of caregivers in cardiac rehabilitation. Clinical decision support has been described by Kannry et al., (2015) as “anything that directly aids in clinical decision-making about individual patients. Decision support can include collegial advice, text references, Web sites and computer systems”. These systems are developed to support and impact clinician decision making at the moment when decisions are made.

Lately clinical decision support has been further developed by implementing different data-collecting techniques like data-mining (Berner & La Lande, 2007). One of the above mentioned programmes applies decision support in telehealth for early cardiac rehabilitation, called *PaTHway*. *PaTHway* is an exercise based telerehabilitation programme using inputs from multiple sensors (motion, heartrate and blood pressure) for analysing the health of the patient and automatically adjusting a training schedule. To do so, rules were made to decide whether an exercise should be more intense or whether the patient should be excluded from the training schedule. (Filos, et al., 2016)

At MST, an early one cardiac telerehabilitation programme has been developed which supports online exercising, telemonitoring and telecommunication. The online exercising module uses a training schedule and a set of rules (decision tree) for personalizing the training schedule per individual patient during the programme. The training schedule consists of exercises for six weeks of training with three days training per week. The training schedule and the decision tree were both developed in the study of de Jong (2017). It is not yet certain if the training schedule and the decision tree contain the right exercises and set of rules. To develop a decision support system for the early online cardiac telerehabilitation programme it is needed to validate the training schedule and the decision tree. The training schedule which the caregivers set up on the program will be compared with the fixed training schedule provided on paper. The same will be done for the decision tree, were

the outcome of the physiotherapists on the program will be compared with the outcome of the decision tree. The aim of this study is to 1) validate the training schedule and the decision tree, and consequently, 2) to define requirements for the development of a decision support system which can automatically personalize the exercises within the training schedule per individual, as part of the early cardiac telerehabilitation program of MST.

The early cardiac telerehabilitation programme, including the decision tree and training schedule are detailed in section 2. Section 3 provides the methodology of the study, and section 4 and 5 respectively discuss the results and discussion.

2. THE EARLY CARDIAC TELEREHABILITATION PROGRAM

In this section we will first discuss the contents of the treatment modules of the early cardiac telerehabilitation program. Thereafter the different components of the decision support system will be examined in more detail, such as the training schedule and the decision tree.

2.1 Treatment modules of the telerehabilitation programme

The early cardiac telerehabilitation program is offered through an online web portal built on the C3PO platform (op den Akker et al., 2013). The webportal has been extensively used for several target groups, including COPD (Dekker- van Weering, 2016). The webportal exists out of 3 different treatment modules: online exercising, telemonitoring and telecommunication.

Module 1: Online exercising

The module online exercising aims to support the patient in reconditioning at home based on the training schedule. The module consists of 60 exercises composed and filmed by physiotherapists. Exercises are divided into 5 exercise categories: strength, thoracic mobility, relaxation, balance and endurance. Each exercise has a video explaining the exercise and has a small description on how to perform the exercise (figure 2). Once every week the physiotherapist selects exercises for patients on the portal for the following week. This selection is done by following a fixed training schedule on paper (paragraph 2.2), which is taken over on the early online cardiac telerehabilitation program.

To personalize the training per individual patient, tailoring is being performed by the physiotherapist in two ways according to a set of rules described on paper (paragraph 2.2):
1.Tailoring for categories (balance, relaxation and stairs exercises)
2.The level of intensity or difficulty for strength and balance exercises, the need and preference for relaxation exercises.

The tailoring for exercises is being performed at the start of the early cardiac telerehabilitaion program. Afterwards the categories are fixed and tailoring will only be performed on the intensity of levels for the exercises once every week, by the physiotherapist on the program.

Module 2: Telemonitoring

With the module telemonitoring, the physiotherapist can monitor the patient's progress or deterioration in health of the patient (parameters). Different standardized questions about the perceived extortion, preference for exercise and usefulness of the exercise are being asked to give an overview of the health status of the patient.

Also, it gives insight in the rehabilitation progress, compliance of the patient and it can provide support for customizing the intensity of the exercises in the programme. By analysing the parameters, the physiotherapist can either adjust the intensity of exercises or contact the patient if it is presumed necessary. The parameters are also made visible for the patients in order to give them insight in their progress and health status.

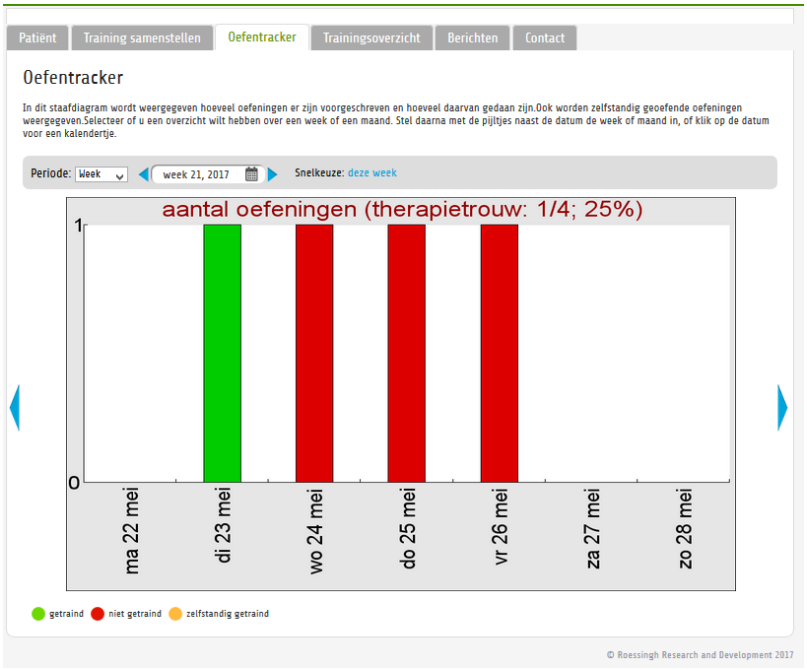

Figure 1: Module 2 Telemonitoring: compliance

Module 3: Telecommunication

With the use of this module, patients and physiotherapists have the possibility to have contact with each other. Both the patient and the physiotherapists are notified when a message is received on the programme. At the beginning of the rehabilitation patients were informed that physiotherapists might not respond immediately and that in case of an emergency, they should contact the hospital. After logging in, both the physiotherapists and patients are notified by an alert symbol, if there are new messages which are displayed in the tab "messages" (berichten). There are two possibilities for sending a message:

1. Messages linked to specific exercises (figure 2)

Both the physiotherapist and the patient have the option to send a message linked to a specific exercise. This can be used to specify if the exercise was too hard or if it went fine. Also, extra

explanation about how to perform the exercise can be provided and both the physiotherapist and patient can respond to questions from either party.

2. General messages (e.g. about the status of rehabilitation)

These are messages which are not linked to specific exercises but are direct messages between the physiotherapist and the patient. This could be messages about the progress of the rehabilitation or about the patients functioning.

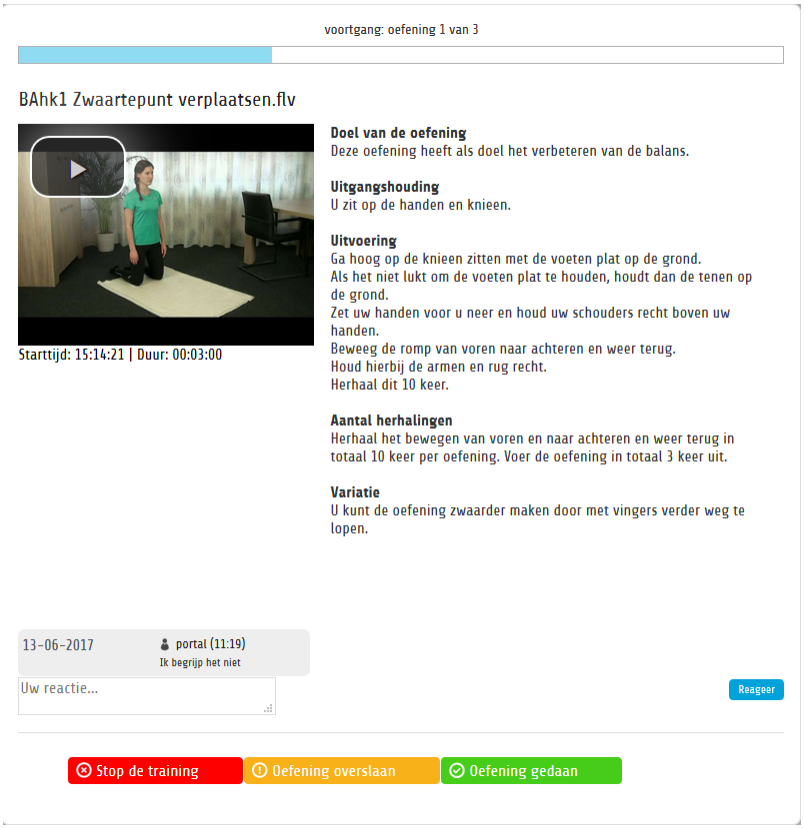

Figure 2: Module 1: online exercising and Module 3: Telecommunication; message linked to exercise.

2.2 Current method for personalization of the training schedule

In this research the decision support is defined as “anything that directly aids in clinical decision-making about individual patients” (Kannry, et al., 2015). An important part of the decision support system in this research is the cohesion between the training schedule and the decision tree which is briefly shown in figure 3. Thereafter, a more specific explanation is given of the two components.

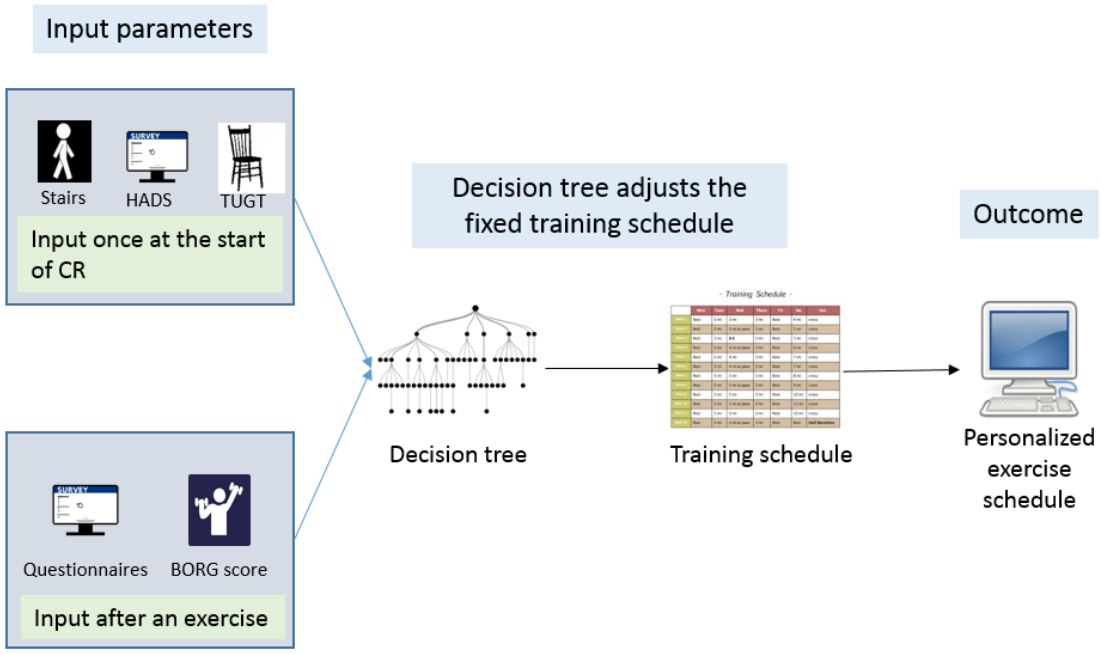

Figure 3: shows an overview of how the parameters are input for the decision tree. The output of the decision tree adjusts the fixed training schedule which results in a personalized training schedule for the patient.

The training schedule (figure 4) is a schedule with 5 exercise categories (strength, thoracic mobility, relaxation, balance and endurance) (de Jong, 2017). Every exercise category has multiple exercises which differ in intensity (Appendix A). The training schedule provides the training content of the 6 weeks of early cardiac telerehabilitation. Every week patients will train three days (Monday, Wednesday and Friday) in the convenience of their own home with approximately six exercises each day. The content of the training schedule has been selected by the rehabilitation committee and the physiotherapists of the MST.

Week	Exercise	Friday	Monday	Wednesday
1	Relaxation	AH1a	AH1b	
	Thoracic mobility	THs 1 – THs 2 – THs 4	THs 1 – THs 2 – THs 4	THs 5 – THs 6 – THs 7
	Exchangeable	THs 3	THs 3	THl 1 – THl 2
	Indication exercise	BAs - ON3	BAs - ON3	BAs - ON4
2	Relaxation	AH1a	AH1b	
	Thoracic mobility	THs 1 – THs 2 – THs 4	THs 1 – THs 2 – THs 4	THs 6 – THs 7
	Exchangeable	THl 1 – BR – (evt THl 2)	THl 1 – BR – (evt THl 2)	ZWb – SQ – OPm – (evt SC)
	Indication exercise	BAs - ON3	BAs - ON3	BAs - ON4
3	Thoracic mobility	THs 1 – THs 2	THs 1 – THs 2	
	Arm muscles	BSa – ZHa	BSa – ZHa	OPm – SC
	Leg muscles	UI	UI	BR – SQ
	Exchangeable	ZWb – TR	ZWb – TR	THs 4 – THs 5
	Indication exercise	BAs – (ON3 of ON2)[1]	BAs – (ON3 of ON2)[1]	BAs - ON4
4	Thoracic mobility	Selection	Selection	
	Arm muscles	OPm	OPm	BSa – ZHa
	Leg muscles	UI – SQ	UI – SQ	BR
	Exchangeable	TR – KU	TR – KU	BAhk – TR – ZWb
	Indication exercise	BAs – (ON3 of ON2)[1]	BAs – (ON3 of ON2)[1]	BAs - (ON4 of ON2 of ON5)[2]
5	Thoracic mobility	Selection	Selection	
	Arm muscles	OPm	OPm	BSa – ZHa
	Leg muscles	SQ - BR	SQ - BR	UI
	Exchangeable	TR – SC – BAhk	TR – SC – BAhk	KU – ZWb
	Indication exercise	BAs – (ON3 of ON2 of ON5 of AH1b)[3]	BAs - (ON3 of ON2 of ON5 of AH1b)[3]	BAs - (ON4 of ON2 of ON5)[2]
6	Thoracic mobility		Selection	
	Arm muscles	BSa – ZHa	BSa – ZHa	OPm – SC
	Leg muscles	UI – SQ	UI – SQ	BR
	Exchangeable	TR – BAhk	TR – BAhk	TR – KU – ZWb
	Indication exercise	BAs - (ON3 of ON2 of ON5 of AH1b)[3]	BAs - (ON3 of ON2 of ON5 of AH1b)[3]	BAL - (ON4 of ON2 of ON5)[2]

AH=Breathing (ademhaling); BAhk=Balance hands and knees (balans handen-knieën); BAs= Balance standing (balans staand); BR= Bridge (bruggetje); BSa=Bending/stretching arm (buigen/strekken arm); KU= Calve (kuit); ON=Relaxation (ontspanning); OPm= Pushup wall (opdrukken muur); SC= Shoulder muscles (schouderspieren (scapula)); SQ=Squat (squat); THl=Thoracic mobility laying down (thoracale mobiliteit lig); THs= Thoracic mobility chair (thoracale mobiliteit stoel); TR= Stairs (trap); UI= Lunges (uitstappen); ZHa= Sideways raising arm (zijwaarts heffen arm); ZWb= Swinging motion (zwaaibeweging been).

Figure 4: Fixed training schedule; the training schedule is made for 6 weeks of training. Every week has 3 training days starting on Friday. Every day has a fixed set of exercises which can be prescribed for that day. The indication exercises are the balance and relaxation exercises. Were it says selection, a free choice can be made by the physiotherapist for selecting an extra exercise. (de Jong, 2017)

To personalize the training schedule to an individual patient, a set of rules, called the decision tree (figure 5) was created (de Jong, 2017). At the start of the cardiac rehabilitation these rules determine, whether a patient needs relaxation and/or balance exercises and if a staircase is present at the patient's home. Balance and relaxation exercises are categorised as indication exercises, staircase exercises are categorized as exchangeable exercises (figure 4). If there is an indication for one or more of these exercises, they will be added to the training schedule of the patient. If there are no indications for one of these exercises, none of them will be added by the physiotherapist to the training schedule.

Besides that, these rules determine the intensity of strength exercise, once every week. The intensity of strength exercises is changed by the physiotherapist using the decision tree in the tab "training overview" (trainingsoverzicht).

First of all, a number of static parameters determine whether the patients have an indication for a category (relaxation or balance) and if a staircase is present of exercise using the following parameters:

- To determine if patients need relaxation exercises, the Hospital Anxiety and Depression Scale (HADS) is used (White, Leach, Sims, & Cottrell, 1999). When a patient scores eight or more on this scale, the patient has an indication for relaxation exercises and they will be present in the training schedule.
- To determine if patients need balance exercises the Timed Up and Go Test (TUGT) is used (Barry, Galvin, Keogh, Horgan, & Fahey, 2014). If a patient has a score of 10 or more seconds, he has an indication for balance exercises.
- To identify if the patients can do the stair exercises, patients are asked if a staircase is present at their home. If the answer is positive, the stair exercises will be present in the training schedule.

Secondly, the intensity of the strength exercises is determined by a dynamic parameter. After every strength exercise, the patients were asked what the perceived level of exertion was based on the BORG score (scale 6 to 20).

The level of intensity of the strength exercise is determined as follows:

- When the score is below or equal to 10, the level of intensity for that exercise should be increased with two.
- When a score of 11 or 12 is given, the level of intensity for that exercise is easy for the patient and should be raised by 1 level.
- When a score of 13 or 14 is given it is considered moderate intensity and preferable for cardiac patients. When a patient gives one of these scores, the level of intensity for that exercise stays the same for one week.
- When a score of 15 or above is given, the level of intensity is too high and the level should not be raised the following week. (Revalidatiecommissie, 2011)

Right after the start of the intervention, physiotherapists considered the determination of levels of intensity in the first decision tree (APPENDIX B) too intensive. They requested the rules mentioned above regarding the level of intensity of exercises. Therefore the decision tree was adapted to figure 5. Right from the start of the intervention the rules stated above were followed.

Finally, after every balance and relaxation exercise, the patient will need to answer fixed questions (figure 5). The answers to these questions are dynamic parameters who will determine if the performed exercise will remain in the schedule for the next week or if the patient requires a different exercise from that category for the next week.

Intake: Week 0		
HADS-score: Anxiety of Depression	0-4	No indication for relaxation exercises.
	5-7	Indication for relaxation exercises and notify the caregiver.
	8-21	Score is too high, add relaxation exercises and notify the caregiver.
TUGT-score	<10 seconds	No indication for balance exercises. Do add the balance hands and knees exercises.
	>10 seconds	Indication for balance exercises standing "staan".
Presence of staircase	Yes	No changes.
	No	Do not select the exercises with stairs involved.
Starting level for upper- and lower extremities	Lower extremities (1 t/m 5)	All the exercises on the same level, except calve "kuit" on level 1.
	Upper extremities (1 t/m 4)	All the exercises on the same level, except for shoulder blades "scapula" on level 1.
Other weeks (every Thursday)		
Strength exercises: BORG-score	≤ 10	2 levels up.
	11,12	1 level up.
	13,14	Level remains.
If the BORG-score is straight for 2 weeks ≥ 15, stop the specific exercise.		
Balance exercises: how much effort?	Score 1: none	1 level up.
	Score 2 t/m 4	Level remains.
Relaxation exercises: Do you have benefit from this exercise?	Yes	Next question is asked
	No	Next question is asked
	Do you want another relaxation exercise? **Yes**	Select different relaxation exercise according to training schedule.
	Do you want another relaxation exercise ? **No**	No changes, continue with the same exercise.
Stepgoal: Achieved last week's goal?	Yes	New stepgoal, average from last week and add 10%.
	No	Stepgoal remains.

Figure 5: Set of rules (decision tree 2)

3. METHODS

3.1 Study design

The aim of this study is to 1) validate the training schedule and the decision tree, and consequently; 2) to define requirements for the development of a decision support system which can automatically personalize the exercises within the training schedule per individual, as part of the early online cardiac telerehabilitation program of MST.

This research is divided in 3 components with corresponding research questions.

Validation Training schedule:
- Does the training schedule set up by the physiotherapist on the program, resemble the fixed training schedule provided on paper?

Validation decision tree:
- Does the prescription of exercise levels by physical therapists in daily care resemble the decisions for exercises made by the decision tree?
- If the physiotherapists do not use the prescription of levels that are provided by the decision tree what is their reasoning that leads to this decision?

Requirements:
- How can the training schedule and decision tree be transformed to a decision support system, to be integrated in the online program for automatic generated exercises for patients based on their perceived extortion and training preferences?
- What are the overall expectations of the physiotherapists with the developed mock-up, in terms of user satisfaction, willingness to use and exercise outcomes?

An overview of the study design can be seen in figure 6. This study started with the validation of the decision tree and the training schedule. The validation was performed by comparing the outcome of the fixed training schedule and the fixed decision tree with the outcome of the physiotherapists. Hereafter, interviews were held with physiotherapists and the observations from the researcher in daily practice were noted. These were used to define requirements for a decision support system for the early online cardiac telerehabilitation program of MST. The requirements were evaluated with the physiotherapists using interviews, and the requirements were adjusted if needed. During the interviews, the physiotherapist needed to give their opinion as to which requirements were most important for a decision support system. Together with the observations by the researcher in daily practice, the 5 most important requirements were selected
and a mock-up of a decision support system was made.

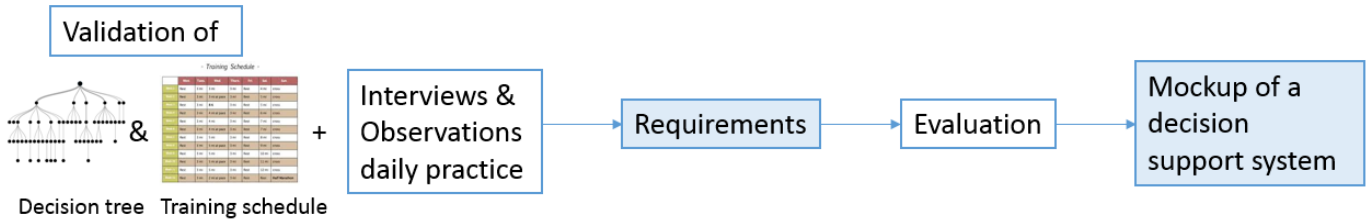

Figure 6: Overview of the study design. First the training schedule and the decision tree were validated. Together with the validated training schedule and the decision tree interviews were held and observations in daily practice were noted. With the use of this information requirements were defined and finally a mock-up of a decision support system was developed.

3.2 Study population

The study population consists of patients who had an open heart surgery, i.e. CABG or valve surgery and were going to participate in cardiac rehabilitation. Patients were asked to participate in the research if they met the following criteria, determined by the treating physician:

- No major complications after surgery;
- Clinically stable and able to perform the exercise program;
- Attending cardiac rehabilitation;
- Access to the internet;
- Control Dutch in writing and reading;
- Age >18;
- Reside in adherence area of the MST.

A medical specialist judged if a patient could join regular cardiac rehabilitation and / or early online cardiac telerehabilitation based on medical criteria.

This research is part of the MATCH study (protocol number: NTR6274) and used the included patients from the leading study. The MATCH study has two patient groups: a control group and an intervention group. For this research, 20 patients from the intervention group were included. Patients were included at the moment the early online cardiac rehabilitation program of MST was introduced.

An informed consent was obtained of all patients included in the MATCH study. Patients were informed about the study by the researchers or if necessary by their physiotherapist if they were suited for the study.

Patients were included in the analysis when at least one level of intensity had been adjusted or if they at least had performed one week of exercises.

3.3 Validation training schedule

Protocol: Once every week physiotherapists were asked to log into the portal and set up a weekly training schedule per patient. This had to be done manually by selecting every exercise per day for all patients. To support them, the fixed training schedule was available on paper but they were not obligated to strictly follow the schedule. If they wanted to make a change in the schedule they were free to do so.

Design: We compared for 2 situations what the training schedule for a patient looks like according to two situations:

1) The fixed training schedule on paper;

2) The actual training schedule set up by the physiotherapists in the early online cardiac telerehabilitation program.

After every training week the training schedule which was set up by the physiotherapists, was compared with the fixed training schedule. In Excel 2012, differences between the 2 situations were marked. In other words, the exercises which would be prescribed by the fixed training schedule were compared with the exercises set up by the physiotherapists in the program. The reasons for the differences between the two situations were collected through a questionnaire filled out by the physiotherapists (APPENDIX C). In this questionnaire, they had to clarify why they selected a different exercise on the program than the fixed training schedule would recommend. Once every week the researcher would collect the questionnaires and note the reasons in the excel file with the corresponding difference. When they did not specify their reason for a difference, the researchers queried the physiotherapists the following week to clarify the differences.

Measurement: The collected data was analysed using Excel 2012. The number of differences were divided by the total number of exercises in order to visualize why and how many differences there were between the two situations. The training schedule was presumed valid when the physiotherapists were satisfied with the outcome rate and by the setup of the adjusted fixed training schedule. To the best of knowledge of the researcher, no similar validation study has been found to validate a comparable training schedule. Therefore we presume the training schedule to be valid if the fixed training schedule prescribes no unwanted exercises for the patient when compared with the outcome of the physiotherapist and when the physiotherapists are satisfied with the training schedule.

3.4 Validation decision tree

Protocol: The physiotherapists were asked to personalize the training schedule according to the set of rules in the decision tree. The physiotherapists were not obliged to strictly follow the decision tree. They were allowed to differ from what the outcome would be according to the decision tree.

Design: We compared the following 2 situations:

1) Changes of exercises according to the decision tree

2) The actual changes of exercises made by the physiotherapists on the early online cardiac telerehabilitation program. All the monitoring parameters are being logged on the portal. The logged parameters were run through the set of rules in the decision tree and choices for the level of intensity for exercises were defined. These were compared with the choices for the level of intensity for exercises, made by the physiotherapist on the program. To support the research in comparing the

outcomes, an algorithm was developed (APPENDIX D). This algorithm was developed together with programmers from Roessingh Research and Development. The parameters were run through the algorithm (which contained the set of rules of the decision tree) and the outcome was the change of intensity level. This was compared with the choice made by the physiotherapist on the program.

If the physiotherapists knowingly made a difference for an exercise than the decision tree would propose, they were asked to fill in a questionnaire (APPENDIX D). In this questionnaire they had to clarify why they did not follow the outcome of the decision tree. Once every week the researcher would collect the questionnaires and note the reasons in the Excel file with the corresponding difference. When the physiotherapists did not specify their reason for a difference, the researcher questioned the physiotherapists the following week.

Measurement: Charts were made in Excel 2012 to visualize the differences between the 2 situations. Differences between the situations were shown in percentages and clusters were made for the reasons of the differences. The set of rules in the decision tree were regarded valid if it was in line with the opinion of the physiotherapists. To the best of knowledge of the researcher, no similar validation of a decision tree has been performed. Therefore, we state the decision tree to be valid if no unwanted exercises are set up by the decision tree and the physiotherapists are satisfied with the set of rules of the decision tree.

3.5 Requirements

The requirements of the decisions support system were defined by using the template from van Velsen (2009). Interviews were held with physiotherapists to examine the need for- and their willingness to use a decision support system. Besides that, physiotherapists were interviewed to ask for recommendations for adjusting the programme, or what extra functionalities they would like apart from the validated decision tree or training schedule.

Observations in daily practice were used to define requirements. These observations were written down by the researcher while conducting the measurements for the research. Also, observations were made when interviewing and inspecting physiotherapists while they were working in the cardiac rehabilitation.

After the requirements were defined, these were discussed with the physiotherapists to analyse if they were correct and which of the requirements were the vital to the physiotherapists. Together with the observations in daily practice, a selection was made of the most important requirements. In consultation with the physiotherapists, 5 phases were determined (table 1), which represented important actions of the program according to the physiotherapists. The requirements who were stated most important to the physiotherapists, fell under these 5 phases.

A mock-up was made of the 5 phases by making screenshots of the portal and adjusting them using the GIMP GNU image manipulation program. The design of the mock-up was evaluated by using the *citizen walkthrough* (van Velsen, van der Geest, ter Hedde, & Derks, 2009). During the citizen walkthrough physiotherapists were asked to perform the task that belonged to the phase, e.g. to make a new account for a patient. Or they were shown how the task was performed automatically by the decision support system. At last they were asked if these adjustments were suitable to fit in

their work. The interviews were noted with their corresponding requirement or phase in the mock-up. The outcomes were analysed and adjustments were made to the requirements and/or mock-up.

Phase	**Description**
1	Making an account for a new patient
2	Determine starting level and adjusting levels of intensity in the following weeks
3	Setting up a new training schedule
4	Filling in the HADS-score on the portal and viewing the HADS score
5	Importance of message

Table 1: 5 phases of the programme and also the 5 phases in the citizen walkthrough.

4. RESULTS.

4.1 Participants

Twenty patients were included in the study, but only 18 patients participated since 2 patients dropped out right after inclusion. Table 2 shows the demographics of the 18 participants. Two physiotherapists (table 3) participated in the study.

Number of participants	18
Avg. Length in centimetres	173,92 (8,92)
Avg. Weight in kilograms	88,6 (16,3)
Avg. Age	67 (9)
Avg. 6 Minute Walking Test	293,00 (125,15)
Male	12
Female	6
No comorbidities	13
Comorbidities	5

Table 2: Characteristics of patients, the 5 self-reported comorbidities are: COPD, diabetic, prostate problems, hernia, intermittent claudication and peptic ulcer disease

Physiotherapist 1	*Age*	39
	Function	Physiotherapist & Manual therapy
	Working experience	15 years
Physiotherapist 2	*Age*	24
	Function	Physiotherapist
	Working experience	2.5 years

Table 3: Characteristics of physiotherapists which participated in the study.

The inclusion of patients (figure 7) started simultaneously with the start of the intervention, i.e. the early online cardiac telerehabilitation program. The inclusion of patients stopped when 20 patients were included.

For validation of the training schedule, 13 patients were analysed with 33 training weeks. When 13 patients were included and had started the program, the researcher and physiotherapists presumed that enough data was available to validate the training schedule. Therefore the decision was made that at that moment in time the available data was used to validate the training schedule.

To validate the decision tree, we waited until 20 patients were included. 4 patients were excluded due to long-term hospital readmission or due to computer problems of the patients. For that reason, data of 16 patients with 42 training weeks was used to validate the decision tree.

For defining and evaluating the requirements two physiotherapists were interviewed. Also, for defining the requirements, the observations of the researcher in daily practice was used.

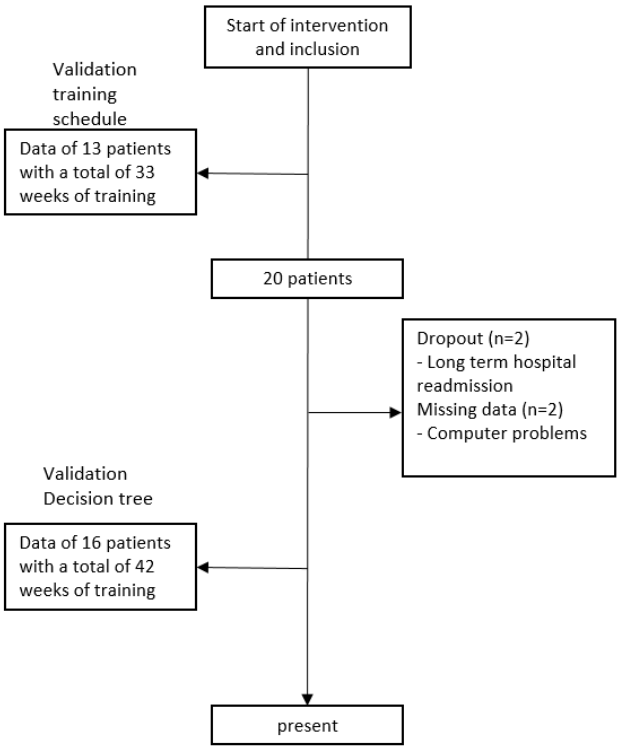

Figure 7: Graphic presentation of the patient flow.

4.2 Validation training schedule

Validation of the training schedule is shown by the percentage of differences observed between 2 situations, for which 5 causes for differences were found. Situation 1) the fixed training schedule and situation 2) the actual training schedule set up by the physiotherapists in the early cardiac online telerehabilitation program. In 64% of the exercises, a difference was found between these two situations, table 4 shows the 5 causes of the differences.

Differences	Percentage of differences
Switching exercises between days (n=6)	24%
More than 6 exercises per day (n=10)	40%
Wrongly selected exercises (n=3)	12%
Indication exercises were selected while the patient had no indication for these exercises (n=1)	4%
Physiotherapist forgot to select an exercise (n=5)	20%

Table 4: 5 causes of the differences between the 2 situations in the training schedule (n=25)

The reasons for these differences, as stated by the physical therapist in the interviews, were caused by the physiotherapist due to not focusing when performing the task, forgetting to select exercises or not being sure if patients had indications for certain exercises. From week 4 in the training schedule, patients were asked to perform 1 of the 4 thoracic mobility (thoraxmobiliteit) exercises selected by the physiotherapist. This was done so the patient could give their own preference to one of the thoracic mobility exercises. This turned out to be not preferable for both the patient and physiotherapist. Patients did not want to choose their own exercises and would rather follow the advice from the physiotherapist. The physiotherapists stated that they also would rather just select one exercise than leave the choice to the patient. They said that the choice for an exercise should be removed and a fixed thoracic mobility exercise should be included in the training schedule.

The maximum number of exercises per day was determined to be six, with a possibility to be seven if the physiotherapists considered it to be desirable. Analysis has shown that when patients had both the indication exercises (i.e. balance, relaxation) and stair exercises, the patient would have too many exercises per day included in the training schedule. Therefore a choice had to be made for replacing exercises from exchangeable exercises with one or more indication exercises.

The physiotherapists stated that stair exercises should always be included in the training schedule if the patient had a staircase. The other exchangeable exercises, besides stair exercises, were allowed to be removed from the training schedule in benefit of the indication exercises.

In 64% of the exercises there were differences between the fixed training schedule and the training schedule set up by the physiotherapist. In nearly all the cases the physiotherapists agreed with what the fixed training schedule would prescribe. Overall, the results show that differences are due to actions performed by the physiotherapists and physiotherapists are satisfied with the training schedule, which indicates that the training schedule seems valid.

4.3 Validation decision tree

Validation of the decision tree is shown by the total number of BORG scores given, as shown in figure 7. The total number of BORG scores given by patients, is visualized in figure 8. 85% of the scores given by patients after performing the exercises, were between BORG score 10 and 15, this range is stated as the "safe range" by physiotherapists. In only 15% of the cases patients have provided a higher or lower BORG score. In 9% of the cases the BORG score was 15 or higher which the danger zone (Revalidatiecommissie, 2011).

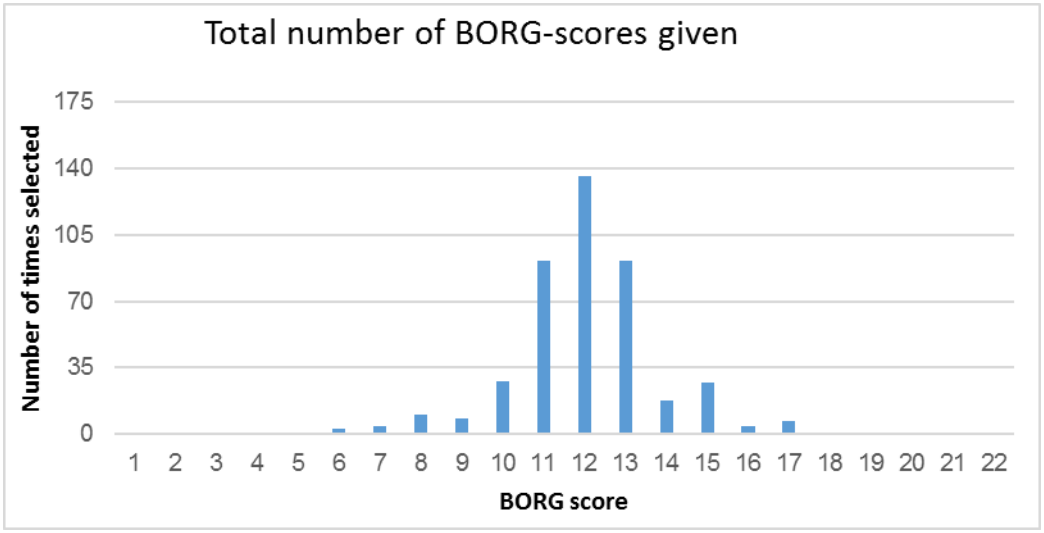

Figure 8 Total amount per Borg-score possible for all patients.

Validation of the decision tree is shown by the differences observed between the two situations as shown in figure 9. The two examined situations where: 1) changes of exercises according to the decision tree and 2) the actual changes of exercises made by the physiotherapists on the early online cardiac telerehabilitation program.

In the first four weeks, decision tree no.1 was used, for which the differences are shown in figure 8. In total, 110 exercises where prescribed during these 4 weeks for which the intensity level was changed 17 times by the physiotherapist. These changes of levels were all performed according to the decision tree. These 17 level changes have been made for 4 exercises, 5 differences were found between the 2 situations out of 110 exercises in total. The reasons for these differences, as stated by physiotherapists in interviews, were due to the fact that physiotherapists found the BORG scores, given by the patients for an exercise, too high to change the level of intensity for the exercise. They wanted to change the range of the BORG scores, at which a level of intensity for an exercise would be changed. For this reason, decision tree no.2 was developed.

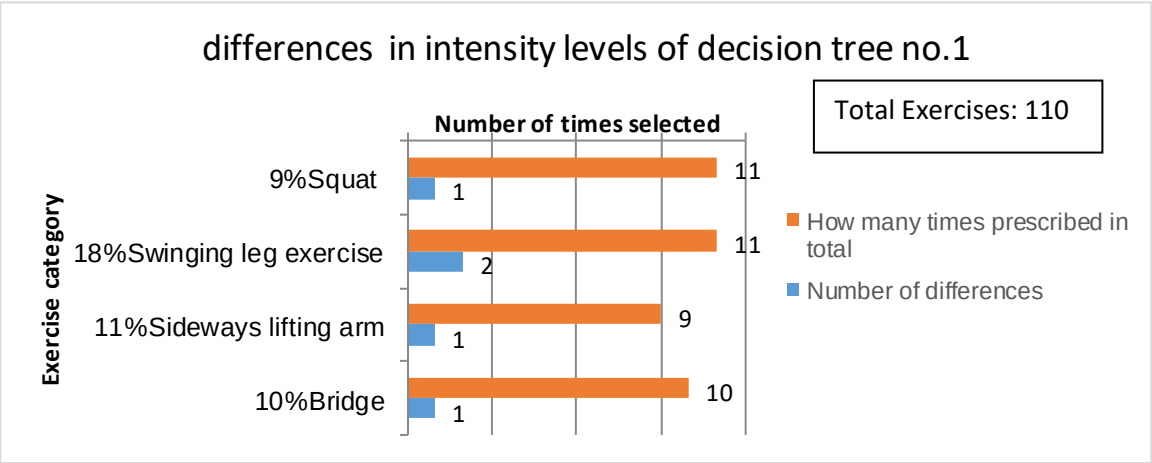

Figure 9: differences in intensity levels of exercises between the 2 situations, regarding decision tree no.1 (used in the first 4 weeks) (n=5)

After the first 4 weeks, decision tree no.2 was used and differences between the 2 situations in levels of intensity per exercise were observed, figure 10. When comparing the 2 situations, 43 differences were found out of 402 exercises in total. Most differences in levels of intensity for exercises can be observed in the exercise "calf muscles" i.e. in 26% of the exercises a difference was found in this category.
The reasons for these differences, as stated by the physical therapist in the interviews, were:

- Preferences for exercises of patients;
- Physiotherapists did not believe the BORG score given by the patient;
- Physiotherapists were not focused on the task and therefore they selected the wrong level.

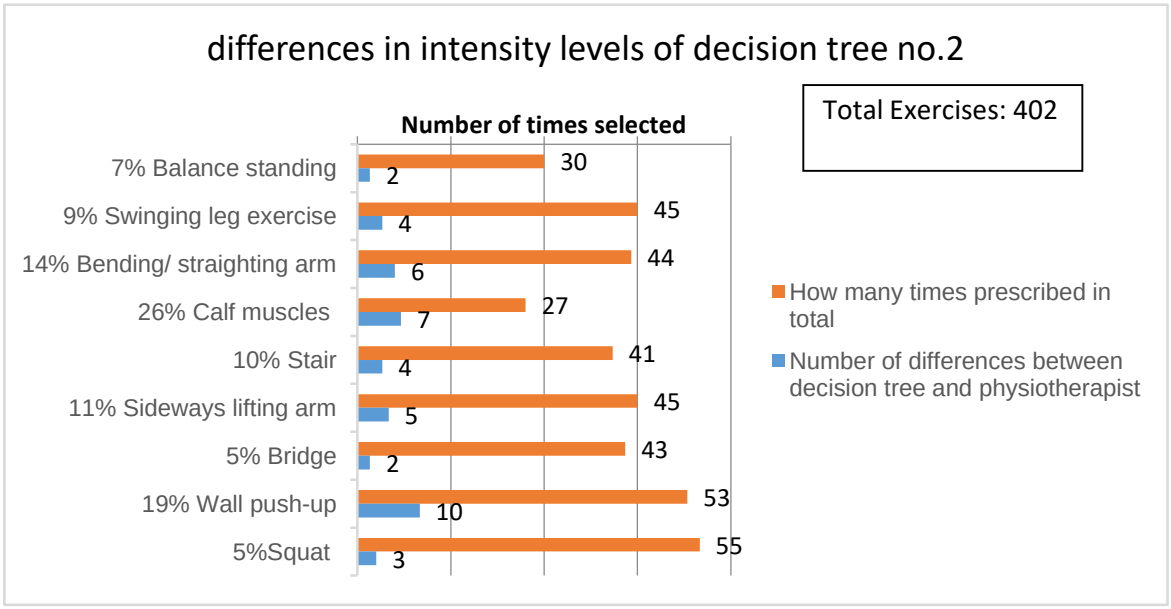

Figure 10: differences in intensity levels of exercises between the 2 situations, regarding the second decision tree (used after the first 4 weeks until moment of analysing) (n=43)

To validate the decision tree, the levels of intensity for exercises of 4 patients who finished the programme, are represented in figure 11. Three exercises ended on the same level for all 4 patients, while 7 exercises ended in different levels of intensity. Physiotherapists stated that these differences were caused by differences in patients' training abilities.

The physiotherapists stated that the physical state and willingness to train was different per patient. Besides that, preferences of patients for specific exercises also determine how much effort patients put into exercises.

Overall, the results show that the differences between the 2 situations were the result of negligence by the physiotherapists. The physiotherapists stated that they were satisfied with the decision tree and indicate that the decision tree seems valid.

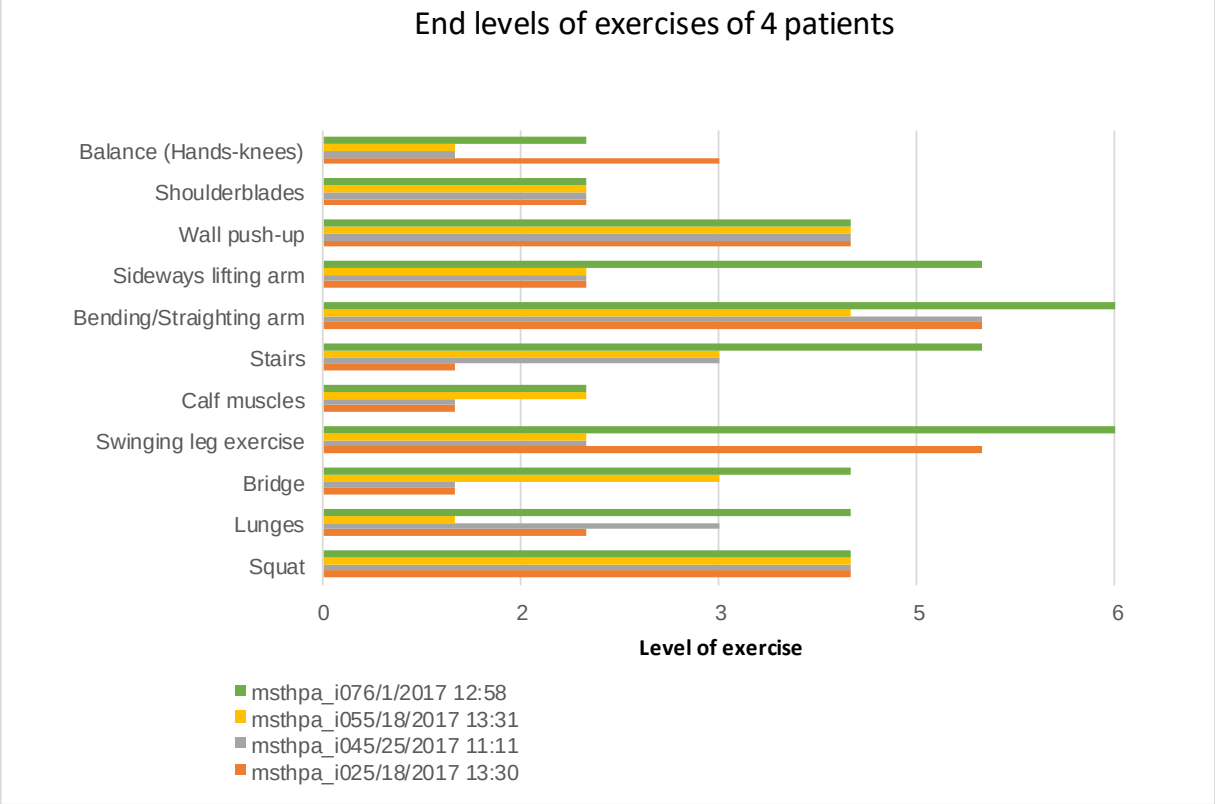

Figure 11: The exercise levels at which the four patients ended the six weeks of cardiac rehabilitation.

4.4 Requirements

A total number of 14 requirements were defined by interviewing the physiotherapists combined with the observations of the researcher in daily practice.
Five requirements shown in table 5, were stated by the physiotherapists to be of most value for their work supported with a decision support system. Together with the physiotherapists these 5 requirements were defined, these requirements were given the priority "high". For a complete overview of requirements see appendix E.

Requirement	Description
1	The training schedule should be embedded into the early online cardiac telerehabilitation program. When setting up a new training week for a patient, the training schedule should automatically be presented as the standard schedule.
2	Indication exercises (stair, balance, relaxation exercises) selected in the tab "training overview" (trainingsoverzicht) should automatically be added to the training schedule.
3	Adjustments in the level of exercises (as stated in the decision tree) should be changed in the training schedule for the next week. The adjustments in level of exercises and change in exercise are based on the BORG-score given and the question do you want other exercises? (wel/geen andere oefening).
4	HADS questionnaire should be embedded into the early online cardiac telerehabilitation program, where patients can fill in the questionnaire. The score should automatically be calculated. And following the DT the relaxation exercises should be selected in the training schedule.
5	Importance and type of message needs to be selectable. (i.e. Question, urgent or informative message)

Table 5: Most important requirements for the decision support system.

Requirements 6 - 14 were derived from the interviews with the physiotherapists and observations by the researcher in daily practice, but were not given a high priority. They could improve the work of the physiotherapists but are not as important as the 5 requirements in table 4.

- Requirements 6, 7, 8: Remarks were made about the maximum number of exercises. In a number of cases where patients had all the indications for special exercises, the maximum number of 6 exercises per day were easily met. Physiotherapists stated that increasing the number of exercises per day from 6 to 7 was preferable. Physiotherapists asked for the option to exclude exercises in the training schedule because patients disliked some exercises. By excluding the disliked exercise, the patient will not see the exercise in future training schedules provided by program.

- Requirements 9, 10: Physiotherapists wanted an automatic synchronization with the accelerometer and the portal, for a valid overview of the number of steps taken by patients. They stated that patients forgot to fill in the number of steps in a few cases. With the synchronized information about the steps from patients, the step goal would be more precise.

- Requirement 11: Physiotherapists stated that notifications for new messages, disappeared to quick. It was unclear for them which message they have read and which not. Therefore, it is desirable that they can deselect the notification per message when they want to.

- Requirement 12: Physiotherapists stated that in some cases it was unclear which scores (HADS, TUGT and stairs) patients had. Physiotherapists find it preferable if they can see scores and select different exercises according to the preferences and scores of patients. Especially, in cases where the maximum of exercises is met and they needed to exchange exercises. Physiotherapists reported that they would like an overview of the parameters of the patients. Therefore, when a patient is selected a text balloon could pop-up on his page displaying and following the user to other tabs with personal information about the patient. Like the name and the scores on HADS, TUGT, 6MWT, presence of stairs and comorbidity.

- Requirements 13, 14: When levels or exercises are changed it is unclear for physiotherapists at what moment this is done. While setting up a schedule or changing the levels they are sometimes interrupted and not focused on the where they were. They found it essential that a date and time is added to see when changes are made in the portal. Besides that, it should be visible in which training week patients currently are. Some patients have a week delay and this could be confusing for physiotherapists. When clearly stating the training week from the training schedule, mistakes could be avoided according to the physiotherapists.

Besides that, the physiotherapists stated that they wanted the exercises arranged in their specific category (strength, thoracic mobility, relaxation, balance and endurance exercises), instead of alphabetic order in which they are currently in the tab “training overview” (trainingsoverzicht).

For evaluation of the mock-up, physiotherapists stated in the interviews and citizen walkthrough, that they had no feedback or comments about the presented mock-up and were highly positive. When asked about the preference for a decision support system the feedback was that this would improve their willingness and satisfaction to use on the portal. Figure 12 shows the three main changes in the portal from the mock-up shown to the physiotherapists. The first image shows extra information about the patient. The boxes can be selected and automatic changes will be made in the tabs “training overview” (trainingsoverzicht) and “set up training” (training samenstellen). The other phases generally showed the physiotherapists that less steps needed to be taken on the portal. For example, the decision support system would automatically set up the training schedule in the first week with the indication exercises. Once every following week, the decision support system would automatically adjust the exercises according to the parameters (BORG score and questions) given by the patients. Physiotherapists stated that they were satisfied with these requirements and mock-up of the decision support system.

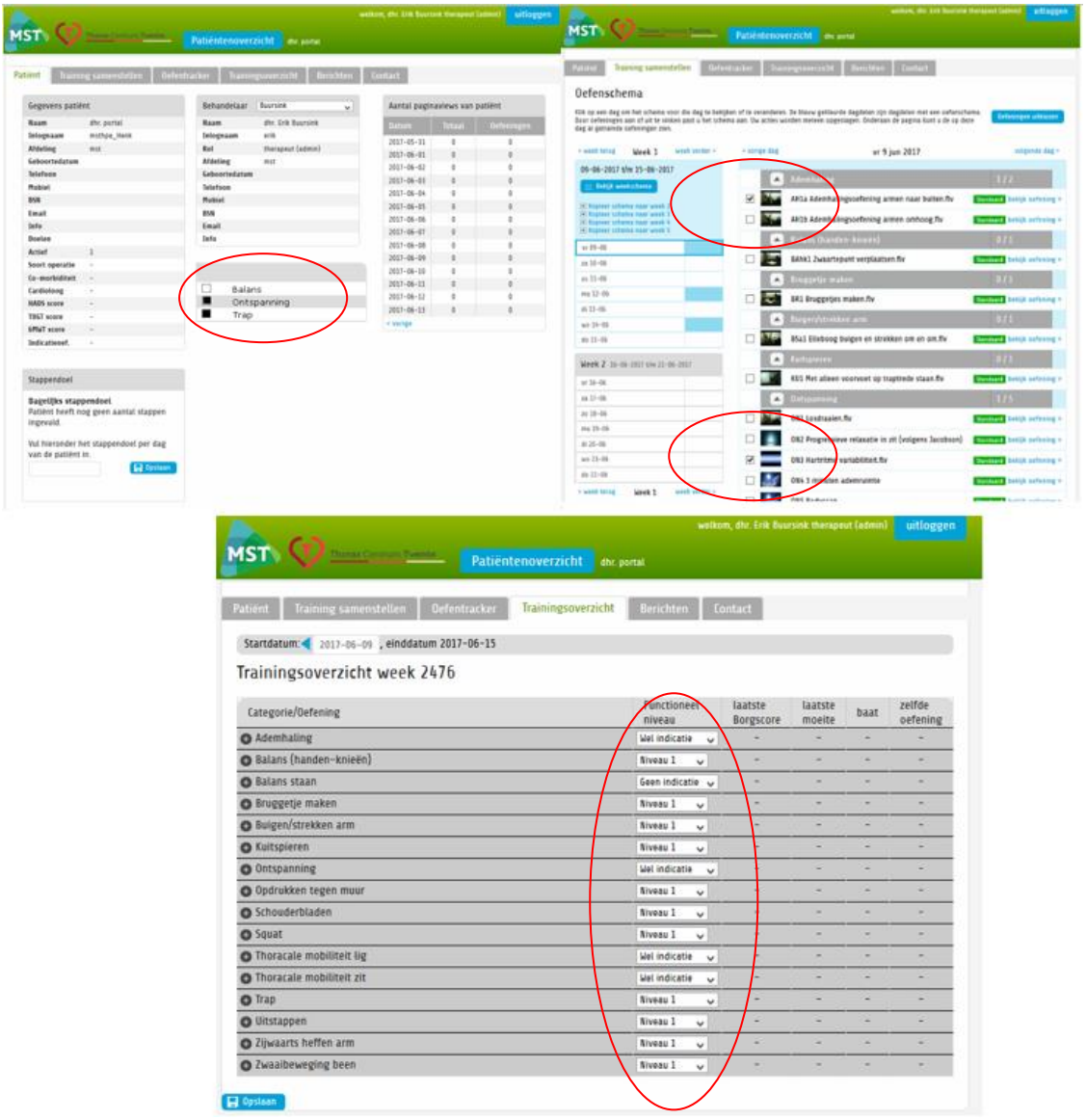

Figure 12: Changes in the portal presented in the mock-up. In the first image a possibility is given to select the indication exercises or stair exercise. When one of these are selected, to corresponding exercises are automatically set in the second and third image.

4.5 High-level architecture

After analysis of the previous results, a high-level architecture was developed for the decision support system within the early online cardiac telerehabilitation program.

The high-level architecture for the decision support system is shown in figure 13. This architecture contains all the components for the online exercise module. All the actions made on the program are performed manually by physiotherapists. When including a decision support system the changing of exercises or the levels of intensity will automatically be performed by the decision support system.

The proposed decision support system will contain the validated decision tree and validated training schedule. The decision support system will automatically process the input given by patients to the questions and the BORG scores, after they performed the exercises, according to the decision tree, and will adjust the training schedule.

At the start of the rehabilitation physiotherapists need to set up a training schedule for the individual patient. The physiotherapist can fill in the scores for the HADS, TUGT and the presence of stairs into the portal so the decision support system can automatically define if the patient has none, one or more indications for stairs, balance or relaxation exercises. In this situation the decision support system will automatically include one of these exercises in the training schedule for that patient.

The adjustment of levels of intensity will be done automatically by the decision support system. At the end of the training week the decision support system will take the latest given BORG score and will then be run through the decision tree and adjustments will be made to the fixed training schedule.

The adjustments of the relaxation and balance exercises will be processed automatically by the decision support system according to the decision tree. At the end of the training week the decision support system will analyse the parameter which belong to the relaxation and balance exercises and will adjust them accordingly to the decision tree.

Hereafter, the decision support system will adjust the fixed training schedule to provide a new personalized training schedule for the individual patient.

Furthermore, the step goal will also be defined according to the decision tree. The number of steps will be uploaded into the program every week. The decision support system will first decide if the step goal is met, if yes it will provide a new goal for the following week or, if not, it will keep the same goal for the next week.

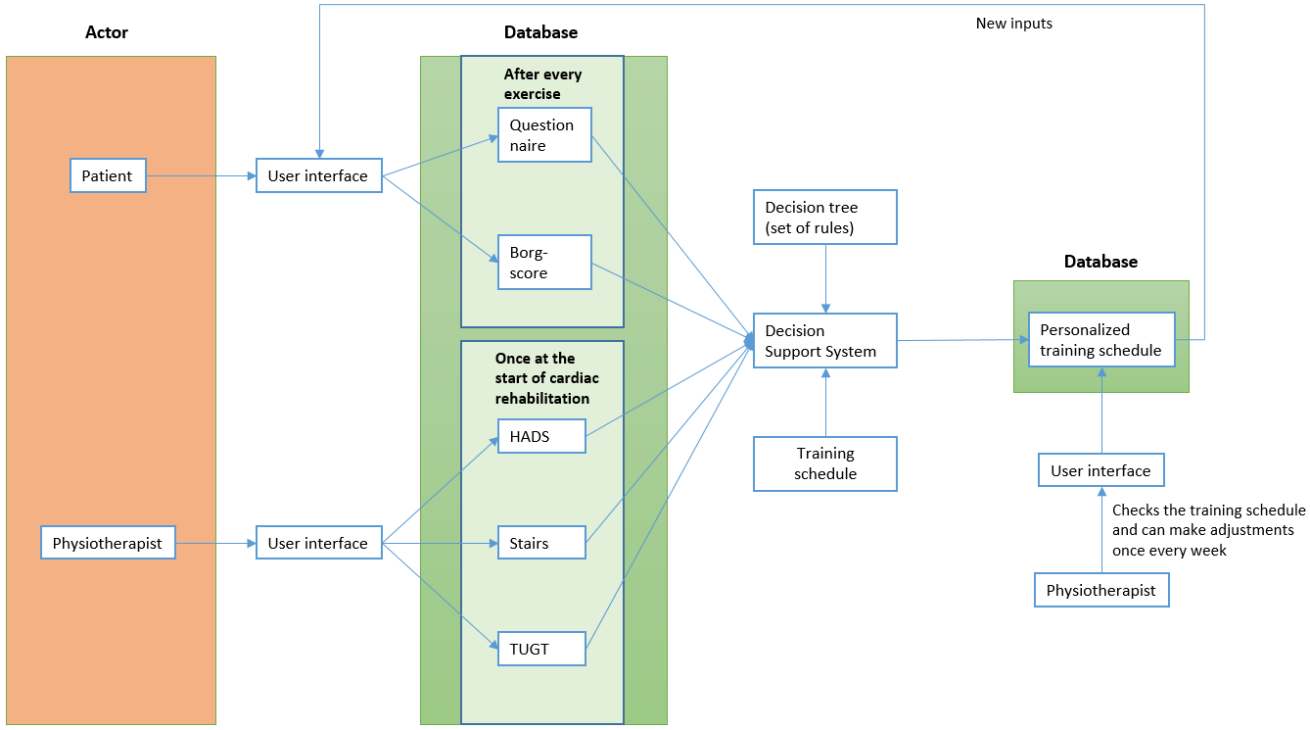

Figure 13: High-level architecture DSS for early online cardiac telerehabilitation program of the MST.

5. DISCUSSION

The aim of this study was to 1) validate the training schedule and the decision tree, and subsequently 2) to define requirements for the development of a decision support system which can automatically personalize the exercises within the training schedule per individual, as part of the early cardiac telerehabilitation program of MST. According to the physiotherapists, the training schedule and the decision tree are validated. Physiotherapists stated to be positive about the programme but requested for extra support when using the early online cardiac telerehabilitation program. By implementing the requirements into a decision support system the work of the physiotherapists is expected to be more efficient and precise.

The decision support system containing the validated training schedule and decision tree seem to fit the needs for the early cardiac telerehabilitation program.

5.1 Validation training schedule

The physiotherapists were overall satisfied with the validated training schedule and indicate the training schedule to be valid. The fixed training schedule was not strictly followed by the physiotherapists. The differences observed were caused by human errors. The differences in the training schedule between the two situations, what the fixed training schedule prescribed and what the physiotherapists set up, were all stated to be human errors. Physiotherapists also stated that the differences were due to work pressure, not being focussed and just selecting the wrong exercise. They stated that an automated system would be preferable to avoid differences like these. They would also like to have an automatic training schedule on the program, which they only need to check the outcome of the decision support system. A decision support system could avoid differences like these to happen and secure a correct training schedule for patients. The only aspect to this is that physiotherapists must be able to adjust the schedule when this seems to be necessary.

Furthermore, the schedule is arranged in a way that it can be adjusted to personalize the exercises for patients together with their preferences for certain exercises. This is in line with the guidelines from Achttien et al. (2015), that states that patients need a personalized schedule with certain categories like, e.g. relaxation, balance, strength, etc. Besides that, the guidelines of Achttien, et al. (2015) state that goals need to be set for patients; in the portal, this is only the case with the number of steps. It seems to be productive to also set goals for daily activities. This can result in improvement in adherence and motivation to exercise as researches like Lee et al. (2005) observed, and stated that setting step goals result in higher adherence and more motivation. The different ways of goal setting can be the following:

1) Lifestyle goals which target the total daily accumulated step count, like used in this portal;

2) Structured goals like walking that lasts for ten minutes or longer at a certain pace.

Kushi et al. (2006) state that the difference between these types of goal setting is not significant in the type 2 diabetic group. However, it may differ in the CR group. This can be a topic for future research. Richardson et al. (2007) states that strength training should be focused on personal goals and restrictions in daily life. This could be more integrated into the portal at the beginning of training. Patients could be asked what their personal goals are and these could be followed during the training weeks.

This study showed that the fixed training schedule was not followed precisely by physiotherapists. In 64% of the cases, a difference was found between the fixed training schedule and the outcome of the physiotherapist. This seems a large difference but almost all the differences were not harmful for the patient. Most differences were due to that physiotherapists were not precisely enough when setting up the training schedule. In nearly all the cases of differences physiotherapists stated that the fixed training schedule was the best option when compared with their own outcome. The physiotherapists stated that they were satisfied with the fixed training schedule and thus indicate that the fixed training schedule is valid.

The validation of the training schedule was performed by examining the differences between the fixed training schedule and the outcomes of the physiotherapists. The outcome of 64% differences between the two situation seemed to be a lot. However, when analysing the reasons behind the differences, they did not represent major or huge flaws in the fixed training schedule. Therefore, the opinion of the researcher is that the 64% should not be a benchmark to use b other studies to validate their training schedule on. This percentage is too high and does not represent the valid training schedule.

5.2 Validation decision tree

The validation of the decision tree showed differences in intensity levels between the 2 situations. The reasons for these differences were mainly human errors. This means that the physiotherapists selected the wrong exercise or level of intensity on the portal. Therefore, it seems that the decision tree is a proper component of the decision support system. Major segments like change in level by means of the Borg score, preference of relaxation exercises and the starting level reached the satisfaction of the researcher and physiotherapists. Most BORG scores were given between 11 and 14 which is stated to be the safe range for the cardiac rehabilitation. Only a few Borg-scores were given above the maximum range of fifteen which indicate the decision tree to be valid regarding the range of BORG scores.

The adjustments in level for exercises are not too high or too low that patients give a Borg score above fifteen or below ten. Only a few differences are observed between the levels set by the physiotherapists and what the level should be according to the decision tree. The reasons given for these differences were almost all human errors. This could be avoided when a decision support system is integrated into the portal.

Results showed that 4 patients whom finished the early cardiac telerehabilitation programme that 4 exercises (e.g. calf muscles, shoulder blades, wall push-ups and squads) ended on the maximum level. This could mean that the lower levels of exercises are too easy for patients. This gives room for further research if certain exercises like calf muscles, shoulder blades, wall push-ups and squads need more intermediate levels. This could also motivate patients to reach a higher level every week and thus provide improvement in exercise motivation. The behaviour modification model from (Heyward & Gibson, 2014) provides tools for setting goals and helps patients to achieve these goals. This might be a valuable adjustment to the decision tree and the program. Moreover, this result only shows the end levels of four patients. More data is needed of patients that completed the program to give a definitive evaluation on this topic.

The validation of the decision tree was purely based on the perception of the physiotherapists and their opinion about the outcome. The differences between the outcome of the fixed decision tree and the outcome of the physiotherapists were examined. For the set of rules in the decision tree, this type of validation seems to be a proper way to validate a decision tree.

5.3 Requirements and need for a decision support system

The validated decision tree and training schedule were successfully defined in requirements that can be utilized for components in the decision support system. The requirements were developed based on the analysed log data and by interviewing physiotherapists and analysing log data, this resulted in 14 requirements. The requirements were approved by the physiotherapists and would be a significant addition to their work.

The interviews and citizen walkthrough performed with the physiotherapists, showed the need for a decision support system. The mock-ups generated no negative feedback from the physiotherapists. According to the physiotherapists, if the decision support system showed in the mock up would be integrated into the portal, the workload and mistakes would be decreased.

To get a clear view of the impact of a decision support system on the current program, further research is needed on this recommendation for a decision support system. A decision support system needs to be developed and tested with the use of real life data. It could be assessed by letting physiotherapists use the new portal and check every change the portal makes. This way, the treatment for patients can be secured and in the meanwhile the decision support system can be validated.

Decision support systems have the ability to significantly improve clinical practice and it is advised to be integrated in daily care. (Kawamoto, Houlihan, Balas, & Lobach, 2005) Furthermore, critical aspects for a decision support system to make it a successful tool are:

- automatic provision of decision support as part of clinician workflow;
- provision of recommendations rather than just assessments;
- provision of decision support at the time;
- location of decision making and computer based decision support;

A systematic review showed that of 32 systems who possessed all four features, 30 (94%) significantly improved clinical practice (Kawamoto, et al., 2005). The proposed decision support system for this portal, includes all four features. Therefore, the possibility that this decision support system will support and improve the care for early cardiac telerehabilitation patients will be likely.

5.4 Limitations

For the data analysis, log data of 16 patients has been used. But only four patients completed the six-week training, this may cause a bias. Despite efforts to include more patients during the period of research we failed to include more patients and data this was due to limited time and resources. Only two physiotherapists were available to perform the tests with the patients and to set up the training schedule every week. If more data is available from more patients who used and finished the portal, the results are more reliable.

Only two physiotherapists contributed to the study. These two physiotherapists are also the only physiotherapists who participated in the development of the program, causing demand characteristics. Which means that both of them are too involved in the study and want to give mostly positive feedbacks. Analysing the decision support system and components with other physiotherapists from other institutions would be recommended to obtain views from participants outside the study.

The adherence of this programme has not yet been evaluated. Nonetheless, the research showed that not every patient performed all their exercises. Patients stated that in the days after surgery they received too much information. Even though the patients received an user manual about the programme and the programme was shown to them by the researchers. Many of the patients called the researchers in the weeks after discharge with questions about the programme. This shows that it was unclear for patients about how the program worked and what was expected of them. This could be a reason for patients to not perform the exercises or not completely follow the instructions provided.

The mock-up made of the decision support system was not entirely evaluated. This was because of limited time and resources. It would be preferable to have a prototype of the decision support system which can be operated by the physiotherapists. A comprehensive usability study can then be performed to analyse experiences and usability of the decision support system.

5.5 Recommendations

Kraal, Peek, Van den Akker-Van Marle, & Kemps, (2014) state that it could be effective to have weekly telephone feedback to discuss patients training progress and goal achievements. This type of feedback can also be performed in the first weeks after discharge from the hospital. This could improve the adherence of and motivation for training of patients. With the use of motivational interviewing, barriers and facilitative factors for adherence regarding the exercises can be discussed. This method of interviewing may overcome barriers for active training and lifestyle change. This is not yet integrated into the portal and adding these kinds of methods can make the program more complete and give extra aspects for patients to maintain their lifestyle change (Kraal, et al., 2014). The only problem with these kinds of feedback is that it will cost the caregivers more time and needs research to see if it fits within the line of work of physiotherapists.

Regarding the comparison between the programs in development *PaTHway*, there are some differences with the *PaTHway* decision support system and the architecture set for the decision support system in this research. The most important differences are the use of sensors in the *PaTHway* project. In this research, it is not implemented to keep the tasks and the set up easy and understandable for the research group. The participants are presumably elderly and less familiar with technologies and how to use them. To implement different sensors like *Pathway*, a new accelerometer can be used, e.g. the MOX physical activity monitor (van der Weegen et al., 2015). This accelerator is stated to be a validated monitor for usage in a clinical environment. This accelerometer has an option to automatically synchronize the data to servers. It is a safe way to transport the data because it is a validated accelerometer for clinical use, it can be certain that the

data obtained is valid and safe. This is due to that the data is automatically synchronised and no interference can occur to adjust the data.

Concluding, it is recommended that future research focusses on the search to expand the programme with different monitoring sensors. These sensors may be able to further optimize the personalization of the exercises for the patients. Additionally, with more monitoring sensors such as heart rate sensors and blood pressure sensors more safety can be assured to the patients. Moreover, a study needs to be performed amongst patients to assess their preferences for the programme and their adherence to the programme. In this way the programme can further be adjusted to the needs of the patients. Furthermore, it is recommended to include more physiotherapists in the study from the MST but also from other hospitals to get a broader perspective on this subject.

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7. APPENDICES

A. Exercises

Soort	Code	Niveau	Oefening	Herhalingen per serie*	Aantal series
Beenspieren: Quadriceps	SQ	1	Met handen op tafel opstaan uit stoel	10	3
	LU	1	Grote stap naar voren + door knieën zakken (om en om)	20 (10 links + 10 rechts)	3
	SQ	2	Met handen op knieën opstaan uit stoel	10	3
	LU	2	Grote stap naar voren, telkens hetzelfde been	20 (10 links + 10 rechts)	3
	SQ	3	Met handen op schouders opstaan uit stoel	10	3
	LU	3	Grote stap naar voren, telkens hetzelfde been	30 (15 links + 15 rechts)	3
	SQ	4	Zonder steunen opstaan uit stoel, bij gaan zitten alleen stoel aantikken met billen	10	3
	LU	4	Grote stap naar voren, telkens hetzelfde been. Bij teruggaan blijft voet van de grond af	20 (10 links + 10 rechts)	3
	SQ	5	Met rug tegen deur of muur naar beneden glijden	5	3
	LU	5	Grote stap naar voren, telkens hetzelfde been. Bij teruggaan blijft voet van de grond af	30 (15 links + 15 rechts)	3
	SQ	6	Met rug tegen deur 'zitten zonder stoel'	30 sec	3
Beenspieren: Hamstrings	HS	1	Bruggetjes maken	10	3
	HS	2	Bruggetjes maken	15	
	HS	3	Bruggetje vasthouden en om en om knie strekken	10 (5 links + 5 rechts)	3
	HS	4	Bruggetje vasthouden en om en om knie strekken	20 (10 links + 10 rechts)	3
	HS	5	Eén been gestrekt houden, dan bruggetjes maken	10	3

Bilspieren	BL	1	Eén been voor- en achterwaarts zwaaien	20 (10 links + 10 rechts)	3
	BL	2	Eén been voor- en achterwaarts zwaaien	40 (20 links + 20 rechts)	3
	BL	3	Eén been zijwaarts heffen en laten zakken	20 (10 links + 10 rechts)	3
	BL	4	Eén been zijwaarts heffen en laten zakken	40 (20 links + 20 rechts)	3
	BL	5	Eén been vlot zijwaarts heffen, afremmen bij het zakken	20 (10 links + 10 rechts)	3
	BL	6	Eén been vlot zijwaarts heffen, afremmen bij het zakken	40 (20 links + 20 rechts)	3
Trap (kracht/conditie)	TR	1	Opstappen en terugstappen	20 (10 links eerst + 10 rechts eerst)	2
	KU	1	Met alleen voorvoet op traptrede staan. Op tenen staan en naar beneden zakken (kuitspieren)	10	3
	TR	2	Opstappen en terugstappen	40 (20 links eerst + 20 rechts eerst)	2
	KU	2	Met alleen voorvoet op traptrede staan. Op tenen staan en naar beneden zakken (kuitspieren)	20	3
	TR	3	Eén been blijft op trede, op en afstappen met andere been	20 (10 links + 10 rechts)	2
	TR	4	Eén been blijft op trede, op en afstappen met andere been	40 (20 links + 20 rechts)	2
	TR	5	Eén been blijft op trede, op en afstappen met andere been. Bij opgaan knie ook heffen	20 (10 links + 10 rechts)	2

Arm-/schouderspieren	DE	1	Op onderarmlengte van deur/muur staan → opdrukken	10	3
	SE	1	Op gehele armlengte van deur/muur staan → met gestrekte armen schouderbladen naar elkaar toe/van elkaar af bewegen	10	3
	DE	2	Op onderarmlengte van deur/muur staan → opdrukken	20	3
	SE	2	Op gehele armlengte van deur/muur staan → met gestrekte armen schouderbladen naar elkaar toe/van elkaar af bewegen	20	3
	DE	3	Op gehele armlengte van deur/muur staan → opdrukken	10	3
	DE	4	Op gehele armlengte van deur/muur staan → opdrukken	20	3
Arm-/schouderspieren met waterflesje (500g)	FL	1	Elleboog buigen en strekken	20 (10 links + 10 rechts)	3
	AB	1	Arm gestrekt zijwaarts optillen tot schouderhoogte	20 (10 links + 10 rechts)	3
	FL	2	Elleboog buigen en strekken	40 (20 links + 20 rechts)	3
	AB	2	Arm gestrekt zijwaarts optillen tot schouderhoogte	40 (20 links + 20 rechts)	3
	FL	3	Naar voren en naar boven boksen vanaf schouder	20 (5 links + 5 rechts voorwaarts 5 links + 5 rechts omhoog)	3
	AB	3	Arm gestrekt zijwaarts optillen tot schouderhoogte, deze positie vasthouden	15 sec (15sec links + rechts gelijktijdig)	3
	FL	4	Naar voren en naar boven boksen vanaf schouder	40	3

				(10 links + 10 rechts voorwaarts 10 links + 10 rechts omhoog)	
	AB	4	Arm gestrekt zijwaarts optillen tot schouderhoogte, deze positie vasthouden	30 sec (15sec links + rechts gelijktijdig)	3
Thoracale mobiliteit: Liggend	THL 1	1	Ruglig, opgetrokken knieën naar links en rechts laten vallen	10	3
	THL 2	1	Ruglig, opgetrokken knieën. Holle en bolle onderrug maken	10	3
Thoracale mobiliteit: Op stoel	THS 1	1	Handen in elkaar, bij inademing armen naar boven strekken, bij uitademing laten zakken	5	3
	THS 2	1	Handen in elkaar, met gestrekte armen draaien met romp	5	3
	THS 3	1	Schouders pro- en retractie	5	3
	THS 4	1	Schouders draaien	5	3
	THS 5	1	Onderkin maken	5	3
	THS 6	1	Lateroflexie CWK	5	3
	THS 7	1	Rotaties CWK	5	3
Oefenigen op handen en knieën	HK	1	Zwaartepunt van tussen handen naar tussen voeten brengen	10	3
	HK	2	Diagonaal arm-been uitstrekken. Om en om	20 (10 links + 10 rechts)	3
	HK	3	Diagonaal arm-been uitrstrekken. Zelfde kant	20 (10 links + 10 rechts)	3
	(HK 4)	(4) is deze gefilmd?	Diagonaal arm-been uitstrekken. Zelfde kant + 3 tellen vasthouden	20 (10 links + 10 rechts)	3
Ontspanning	ON	1	Losdraaien		
	ON2a	1	Progressieve relaxatie zit (volgens Jacobson)		

	ON2b	1	Progressieve relaxatie lig (volgens Jacobson)		
	ON3	1	Hartritmevariabiliteit biofeedback		
	ON4	1	3 minuten ademruimte		
	ON5	1	Bodyscan		
	AH1a	1	Ademhalingsoefening (in: armen naar buiten; uit: armen naar binnen)		
	AH1b	1	Ademhalingsoefening (in: armen omhoog; uit: handen kruis)		
Balans	BAL	1	Staan met voeten aan elkaar	10 seconden	3
	BAL	2	Staan met hak ene voet voor de tenen van de andere voet	20 seconden (10sec ene houding + 10sec andere houding)	3
	BAL	3	Op één been staan	20 seconden (10sec ene houding + 10sec andere houding)	3

AB=abductie; AH=ademhaling; BAL=balans; BL=bilspieren; DE= deltoideus; FL=flexie; HS=hamstrings; HK= hakken-knieen; KU=kuit; LU=lunge (quadriceps) ON= ontspanning; SE=seratus; SQ=squat (quadriceps); THL=thoracale mobiliteit lig; THS=thoracale mobiliteit stoel; TR = trap

B. Decision tree no.1

Intake: Week 0		
HADS-score: Anxiety of Depression	0-4	Geen indicatie voor ontspanningsoefeningen.
	5-7	Voeg ontspanningsoefeningen toe.
	8-21	Te hoge score, geef melding aan coördinator.
TUGT-score	<10 seconden	Geen indicatie, wel *''handen en knieën''* oefeningen.
	>10 seconden	Indicatie voor balansoefeningen *''staan''*.
Trap aanwezig?	Ja	Geen wijzigingen
	Nee	Oefeningen met trap niet selecteren.
Beginniveau voor onderste en bovenste extremiteiten	Onderste extremiteiten	Alle oefeningen op hetzelfde level, behalve *"kuit"* standaard op level 1.
	Bovenste extremiteiten	Alle oefeningen op hetzelfde level, behalve *scapula* standard op level 1.
Overige weken (elke donderdag)		
Krachtoefeningen: BORG-score	< 11	2 levels omhoog.
	11 t/m 14	1 level omhoog.
	≥ 15	Level blijft gelijk.
Wanneer BORG-score 2 weken achter elkaar ≥ 15, contact zoeken met de zorgverlener en patiënt.		
Balansoefeningen: hoeveel moeite?	Antwoord: Geen	1 level omhoog.
	Antwoord: alle andere	Level blijft gelijk.
Ontspanningsoefeningen: Hebt u baat bij de oefening?	Ja	Geen wijzigingen.
	Nee	Vervolgvraag.
	Wilt u een andere ontspanningsoefening? **Ja**	Andere ontspanningsoefening selecteren.
	Wilt u een andere ontspanningsoefening? **Nee**	Geen verandering, met patiënt overleggen welke voorkeur hij heeft.
Stepgoal: afgelopen week gehaald?	Nee	Stepgoal blijft gelijk.
	Ja	Nieuwe stepgoal: gemiddelde van afgelopen week + 10%.

C. Questionnaires

Datum:

Naam fysiotherapeut:

Code patiënt:

Code oefening:
Reden van ander level:

Code oefening:
Reden van ander level:

Code oefening:
Reden van ander level:

Code oefening:
Reden van ander level:

Hebt u zich aan het weekschema gehouden, aantal en type oefeningen, ja/nee?
Indien nee, waarom niet?

Datum:

Naam fysiotherapeut:

Code patiënt:

1. HADS-score, ontspanningsoefeningen

   Indicatie volgens het protocol: ja/nee? Indien nee, waarom niet?

2. Timed up and go score, balansoefeningen
   Indicatie volgens het protocol: ja/nee? Indien nee, waarom niet?

3. Level of strength: startniveau krachtoefeningen onderste extremiteit en bovenste extremiteit
   Waar is de waarde op gebaseerd die u, voor beide categorieën, hebt ingevuld?

4. Hebt u zich aan het weekschema gehouden, aantal en type oefeningen, ja/nee?
   Indien nee, waarom niet?

D. Algorithm.

```
int calcProtocol1Level(int prevLevel, Integer borg,
              Integer effort) {
       if (borg != null) {
              if (borg < 11)
                     return prevLevel + 2;
              else if (borg < 15)
                     return prevLevel + 1;
              else
                     return prevLevel;
       } else {
              if (effort == 1)
                     return prevLevel + 1;
              else
                     return prevLevel;
       }
}
```

```
int calcProtocol2Level(int prevLevel, Integer borg,
                Integer effort) {
        if (borg != null) {
                if (borg < 11)
                        return prevLevel + 2;
                else if (borg < 13)
                        return prevLevel + 1;
                else
                        return prevLevel;
        } else {
                if (effort == 1)
                        return prevLevel + 1;
                else
                        return prevLevel;
        }
}
```

E. REQUIREMENTS

Requirement #: 1	**Requirement type:** Functions & events
Description: The training schedule should be embedded into the program. When setting up a new training week for a patient, the training schedule should be automatically be presented as the standard schedule.	
Rationale: To minimize the amount of work for the physiotherapists and to minimize the risk for selecting wrong exercises.	
Source: Interviews and experience with patients and physiotherapists	
Fit criteria **Acceptance testing**: Physiotherapists should agree with the exercise schedule and may only make small adjustments to fit the requests of the patients. **Usability testing**: While setting up a new week schedule, the correct exercise schedule should be presented according to the protocol. **Summative evaluation**:	
Priority: High	**Conflicts:** none.
History: created on may 23th	
Requirement #:	**Requirement type:** Functions & events

Requirement #: 2	**Requirement type:** Functions & events
Description: Indication exercises (trap, balans, ontspannings oefeningen) selected in the “trainingsoverzicht” should automatically be added to the training schedule.	
Rationale: To ensure that the training schedule is as personalized as possible, regarding the inputs, for the patient.	
Source: Interviews and experience with patients and physiotherapists	

Fit criteria **Acceptance testing**: Physiotherapists should agree with the exercise schedule and it should meet the rules mentioned in the protocol. **Usability testing**: While setting up a new week schedule, the correct exercise schedule should be presented. **Summative evaluation**:	
Priority: High	**Conflicts:** none.
History: created on may 23th	

Requirement #: 3	**Requirement type:** Functions & events
Description: Adjustments in the level of intensity of exercises (as stated in the decision tree) should be changed in the training schedule for the next week. The adjustments in level of exercises and change in exercise are based on the BORG-score given and the question: do you want another exercise? (“wel/geen andere oefening”).	
Rationale: To minimize the amount of work for the physiotherapists and to minimize the risk for selecting wrong levels.	
Source: Interviews and experience with patients and physiotherapists	
Fit criteria **Acceptance testing**: Physiotherapists should agree with the exercise schedule and it should meet the rules mentioned in the protocol. **Usability testing**: When comparing the selections made by the system with the decisions made by the protocol. **Summative evaluation**: not applicable	
Priority: High	**Conflicts:** Possible conflict with the messages send by the patients. They might give a low BORG-score while messaging that the exercise was “hard”.
History: created on may 23th	

Requirement #: 4	**Requirement type:** Functions & events
Description: HADS questionnaire should be embedded into the program where patients can fill in the questionnaire. The score should automatically be calculated. And following the protocol the "ontspannings oefening" should be selected in the training schedule.	
Rationale: To ensure that the questionnaire can be filled in on the portal and the score will be calculated. Furthermore, to automatically be adjusted in the "trainingsoverzicht" with its indication as stated in the protocol.	
Source: Interviews and experience with patients and physiotherapists.	
Fit criteria **Acceptance testing**: Physiotherapists should agree with the exercise schedule and it should meet the rules mentioned in the protocol. **Usability testing**: not applicable **Summative evaluation**: not applicable	
Priority: High	**Conflicts:** none.
History: created on may 23th	

Requirement #: 5	**Requirement type:** Functions & events
Description: Importance and type of message needs to be selectable. (i.e. Question, urgent or informative message)	
Rationale: To ensure that messages which are important for the physiotherapist stand out from the less important messages.	
Source: Interviews and experience with patients and physiotherapists	
Fit criteria **Acceptance testing**: **Usability testing**: **Summative evaluation**:	
Priority: High	**Conflicts:** Patients might not select the importance of a

	message, and thus an important message may be unnoticed.
History: created on may 23th	

Requirement #: 6	**Requirement type:** Functions & events
Description: There should be options to select or deselect indications exercises (trap-, balans- en ontspanningsoefeningen). When an indication is selected these exercises should immediately be added to the training schedule or when it is deselected it should be removed from the training schedule.	
Rationale: With this option, it is less work for the physiotherapist to select and adjust the training schedule.	
Source: Interviews and experience with patients and physiotherapists	
Fit criteria **Acceptance testing**: Physiotherapists should agree with the exercise schedule and it should meet the rules mentioned in the protocol. **Usability testing**: **Summative evaluation**: not applicable	
Priority: medium	**Conflicts:** none.
History: created on may 23th	

Requirement #: 7	**Requirement type:** Functions & events
Description: A maximum of seven exercises per day should be set in de training schedule. When indication exercises (trap, balans, ontspannings oefeningen) are selected they should be exchanged with the exchangeable exercises in the training schedule.	
Rationale: To not make the exercise too exhausting for the patient.	
Source: Interviews and experience with patients and physiotherapists	

Fit criteria **Acceptance testing**: When setting up a new week schedule, the correct exercise schedule should be presented by means of indication exercises and number of exercises **Usability testing**: **Summative evaluation**:	
Priority: Medium	**Conflicts:** Possible preferable exercises are left out because the system does not select them.
History: created on may 23th	

Requirement #: 8	**Requirement type:** Functions & events
Description: Physiotherapists should be able to add or delete an exercise from the week schedule.	
Rationale: To ensure that physiotherapists can adjust the week schedule in such a way that it is suited for the patient of needed.	
Source: Interviews and experience with patients and physiotherapists.	
Fit criteria **Acceptance testing**: not applicable **Usability testing**: not applicable **Summative evaluation**: not applicable	
Priority: High	**Conflicts:** none.
History: created on may 23th	

Requirement #: 9	**Requirement type:** Functions & events
Description: Every Wednesday the data from the step counter, which stores his data online, should be uploaded into the portal.	

Rationale: To ensure that the amount of activity/steps is correct and the patient gets an accurate step goal for the following week .	
Source: Interviews and experience with patients and physiotherapists.	
Fit criteria **Acceptance testing**: not applicable **Usability testing**: Overtime comparison with the automatic activity goal and the goal set by the physiotherapists. **Summative evaluation**: not applicable	
Priority: Medium	**Conflicts:** The automatic made activity goal might not be in line with the opinion of the physiotherapist.
History: created on may 23th	

Requirement #: 10	**Requirement type:** Functions & events
Description: If the step goal of the previous week is achieved, an average per day should be calculated (from total of 7 days) and 10% should be added. This is then presented on Friday (the first training day of the training week) as the step goal for the next week. If the step goal of the previous week is not achieved, to same step goal remains.	
Rationale: To ensure that the amount of activity/steps is correct and the patient gets an accurate step goal for the following week.	
Source: Interviews and experience with patients and physiotherapists.	
Fit criteria **Acceptance testing**: not applicable **Usability testing**: Overtime comparison with the automatic activity goal and the goal set by the physiotherapists. **Summative evaluation**: not applicable	
Priority: Medium	**Conflicts:** The automatic made activity goal might not be in line with the opinion of the physiotherapist.
History: created on may 23th	

Requirement #: 11	**Requirement type:** Functions & events
Description: An option should be selectable so that alerts of messages only disappear when the physiotherapists deletes the alert.	
Rationale: To ensure that alerts disappear too soon and the user has to search to find the message again after visiting another page.	
Source: Interviews and experience with patients and physiotherapists	
Fit criteria **Acceptance testing**: **Usability testing**: **Summative evaluation**:	
Priority: Low	**Conflicts:** Alerts may not be deleted and may be selected/read again.
History: created on may 23th	

Requirement #: 12	**Requirement type:** Functions & events
Description: A pop-up balloon should follow the user on the portal with information about the specific patient like, the HADS score, TUGT score, 6MWT, stairs and comorbidities.	
Rationale: With this overview, the physiotherapists do not need to switch back to the previous page to identify which exercises the patient needs to do and what the indications or comorbidities are.	
Source: Interviews and experience with patients and physiotherapists	
Fit criteria **Acceptance testing**: **Usability testing**: **Summative evaluation**:	

Priority: Medium	**Conflicts:** none.
History: created on may 23th	

Requirement #: 13	**Requirement type:** Functions & events
Description: Divide the exercises by category in the "trainingsschema" into (upper and lower extremity, relaxing exercises, breath exercises and balance exercises)	
Rationale: To ensure that the overview for the physiotherapists is clear and to avoid mistakes.	
Source: Interviews and experience with patients and physiotherapists	
Fit criteria **Acceptance testing**: **Usability testing**: **Summative evaluation**:	
Priority: Low	**Conflicts:** none.
History: created on may 3th	

Requirement #: 14	**Requirement type:** Functions & events
Description: The tab "trainingsoverzicht" should provide an overview of last week training settings.	
Rationale: To ensure that the physiotherapists can compare the prior week with the following.	
Source: Interviews and experience with patients and physiotherapists	
Fit criteria **Acceptance testing**: **Usability testing**: **Summative evaluation**:	
Priority: Medium	**Conflicts:** none.
History: created on may 3th	