

■ Telerehabilitation in the Treatment of Coronary Artery Disease

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Introduction

The effectiveness of cardiac rehabilitation (CR) for patients suffering from cardiovascular diseases has been proven.^{1,2} Traditionally, the CR programs are hospital based (ambulatory or in-patient) and are supported by a multi-disciplinary team. Core components of CR are physical activity and exercise training, behaviour-modification strategies and risk-factor management, nutritional counselling and psychosocial management.

The impact of exercise training has been investigated for patients suffering from all different manifestations of coronary artery disease (infarction, PCI, CABG) and for patients with heart failure (HF). Exercise training influences the main pathophysiological mechanisms that induce exercise intolerance and has a positive influence on risk factors and endothelial function.³ Several studies⁴ also demonstrate that abnormalities of both skeletal muscle and vasomotor tone, characteristic of HF, can be reversed with exercise training. Furthermore, regular physical activity increases the vascular expression of anti-oxidative radical scavenger enzymes in patients with coronary artery disease⁵ and decreases the sympathetic nerve activity in HF patients.⁶ Besides neurohormonal adaptations exercise training also effects inflammation by reducing the level of cytokines within the blood.

Why is Cardiac Rehabilitation Underused?

Despite the overwhelming evidence that supports the effectiveness of in-hospital CR, uptake rates remain poor. A variety of patient and provider factors contribute to these poor uptake rates. Patients regularly choose not to attend the rehabilitation sessions in the hospital due to a lack of access to transport, ill-health, time and scheduling commitments associated with returning to work or reimbursement issues.⁷ However non-compliance with lifestyle and risk factor recommendations in CR is associated with adverse outcomes. For example, Van der Wal *et al.*⁸ demonstrated that non-compliance with exercise training was associated with an increased risk for mortality and HF readmission.

Another worrisome finding concerns the progressive worsening of various cardiovascular disease risk factors during the months after in-clinic CR. Hansen *et al.*⁹ found that in patients with coronary artery

disease following a three month program of in-clinic CR, the cardiovascular disease risk profile worsened significantly during the 18 months after the in-clinic CR as a result of non-adherence to the recommended minimal physical activity level.

Cardiac Telerehabilitation as Alternative

During the last decade however researchers started to search for potential alternatives to overcome the problems with hospital based CR described above.

One alternative is the home based CR, where the patient exercises at home and is in contact with his medical supervisor by means of telephone calls, video conferencing, the internet or other communication media.

Researchers from the NHS in Cornwall, the Peninsula Medical School, the Agency for Health Technology Assessment in Warsaw and the University of Birmingham have analysed 12 studies relating to cardiac rehabilitation.⁷ This systematic review, which included data from 1938 participants, found that there was no difference between home based and centre based rehabilitation for a number of issues including mortality, cardiac events, exercise capacity, risk factors that can be modified (such as smoking, high blood pressure, total cholesterol) and quality of life in people at a low risk of further events after myocardial infarction or revascularisation. The study also found some evidence that home based CR participants were more likely to stick to their rehabilitation regime. This is an important point, because poor participation can be a weakness in some cardiac rehabilitation programmes delivered from centre based settings such as hospitals or gyms.

Furthermore, the concept of telerehabilitation has been introduced recently. In telerehabilitation, the patient's exercise is monitored from a distance, with regular feedback. This monitoring is done using several different monitoring devices (accelerometers, pedometers, online questionnaires etc) and is transmitted by mobile phone or the internet. The recent advances in information and communication technologies (ICT) can be used to enhance the delivery of a telerehabilitation program.

Formative research results indicated that telerehabilitation could have numerous advantages over conventional CR. Cardiac patients can be reached in an effective way, even if they can not attend the rehabilitation centre due to a lack of time or transport, or due to ill-health.⁷

One possible drawback for telerehabilitation is the difficulty in monitoring adverse reactions by patients from a distance. Fortunately, in the selected patients, the risk of adverse reactions during the rehabilitation program is very low, allowing to introduce this kind of supervision to the majority of patients. Also while the younger patients are used to working with ICT applications, most of the older patients are not acquainted with this technology. They sometimes do not have mobile phones or do not know how to access the internet properly. Therefore age is sometimes considered a potential barrier for telerehabilitation.

Numerous devices have been described in the literature that can be used in a telerehabilitation setting such as a cardiac patient training companion (CPTC). The CPTC is a theoretical concept, defined as the ideal apparatus specifically designed for the cardiac patient. It is able to record and store the patient's data accurately and to transfer these data automatically to a platform that is available for the patient's caregivers.

Requirements for a Cardiac Patient Training Companion

A CPTC (Figure 1) should preferentially have the following characteristics:¹¹

Feedback: the patient should receive encouragement that their efforts pay off to reduce the risk that they could relapse. Therefore the CPTC should give the patient easy understandable feedback on their progress

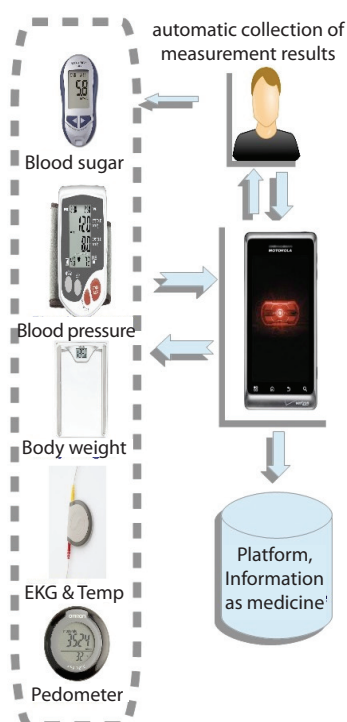


Figure 1. Concept of a cardiac patient training companion.

and this is preferable in real time. This feedback also helps for those patients who do not believe that they will succeed (lack of self-efficacy) to enhance their health condition. The Telerehab II study (currently conducted in the Jessa Hospital, Belgium) uses a motion sensor with automated feedback by email or SMS. The effect of this feedback on the activity level of the participating patients will be investigated in this study.

Low tech: most of the CR patients that can benefit from the CPTC are older and have less experience

with complex technical devices and computers. In addition these patients can also suffer from ageing deficiencies such as bad sight making the manipulation of these devices more difficult. A CPTC should therefore be easy to use, possibly remotely configurable.

Accurate: accuracy of the collected data, such as heart rate, the number of steps, the energy expenditure etc. is primordial. The CPTC serves as a tool to remotely provide the caregivers with patient data. Based on those data, caregivers will make decisions and provide feedback to their patients.

Convenience: if the patient needs a long preparation to "wire up" the devices, such as a heart beat strap that has to be mounted directly on their breast, the solution is often too cumbersome for the patient resulting in a partial or complete abandoning of the use of such devices. Patients convenience will increase if the CPTC has additional functionalities such as a watch or mobile phone.

Low power: it is frustrating when a car or cell phone cannot be used because of an empty battery. This is also the case for the CPTC. Most current designs run out of power quite quickly. One day of autonomy is often not enough. Autonomy is another characteristic to consider when comparing CPTC alternatives.

Alarm: Cardiac revalidation patients have a severe heart condition. Therefore, alarming caregivers when the recorded data from the patient go out of predefined limits is an additional requirement. An example of such a functionality is found in the device with a tele-event-Holter ECG feature used by Piotrowicz *et al.*^{14,15} that enabled the patient to register an ECG recording immediately whenever a worrying symptom occurred.

Large storage capacity: the rehabilitation process takes a long time. Often the patient can do revalidation exercises such as staircase climbing from time to time, not necessarily each day following a regular training scheme. A CPTC with sufficient on board memory to do precise book keeping over longer periods, possibly months or years, constitutes an advantage for the patient and the caregiver.

Automated data transfer: today's follow-ups of a patient often have the format of regular counseling. The cardiologist only has the sparse information they can collect during the visit of the patient. This leads to more difficult analyses than would be the case if they had access to all the data that could have been collected by the CPTC. Therefore remote data transfer from the CPTC to a centre managed by caregivers is preferable. This remote data transfer can be completely automated, partly automated with some data collected and transmitted by the patient himself or completely manual requiring the patient to keep a diary.

Mobility: patient's ability to combine the rehabilitation process with work, vacation, family visits etc. will increase if this remote data transfer can be done using a mobile device and is not tied to a

preconceived environment such as their home.

Security: patient's data is personal information within the European Data Protection Directive (95/46 EC). This directive classifies health related information as the most personal information of an individual. A CPTC needs to conform to this European legislation and this implies that collected information is secured in a way that access to this information is restricted to the patient and caregiver.

Affordable: of course the solution needs to be affordable for the patient and this implies a low cost for the CPTC or the availability of an entry level solution that has the most important functionalities.

Two way communication: When the CPTC raises an urgency that triggers an intervention of caregivers, a two way communication of the caregiver with the CPTC can be useful to avoid unnecessary interventions. If the caregiver can use the CPTC to inform the patient about this urgency, it is still possible for the patient to flag the incident for example as the result of a wrong manipulation of the device if this would be the case.

Findings of Cardiac Telerehabilitation Studies

Mattila *et al.*¹² developed a measurement system and implemented the necessary software tools on a mobile phone platform enabling patients to participate in a home-based CR program. The framework they proposed is composed of a patient sensor and the mobile exercise application TuneWalk. The patient sensors were able to acquire ECG readings and movement activity from the patient by means of a three-channel acceleration signal along the X, Y and Z axes. These registrations could be transferred to a mobile phone via Bluetooth. TuneWalk was the mobile exercise application that communicated with the sensor device, stored the accumulated data and sent them to a web application server for remote exercise performance analysis and consultation by the patient's personal mentor. A randomised controlled trial (RCT) using the TuneWalk application is now being conducted.

The Care Assessment Platform (CAP) is a model for out-patient CR developed by Varnfield *et al.*,¹ which integrates home-based CR with mobile phones and web-services. Walters *et al.*¹³ performed a RCT to compare the CAP model with the standard in clinic CR model. In the CAP model, a mobile phone that has an integrated accelerometer application for recording exercise information, is given to the patients. All data are synchronised to a remote web portal. Mentors view and assess patient's measurements and health data on the portal and use this information for individual feedback and goals setting during weekly telephone monitoring sessions. A RCT of the CAP program versus an in-clinic CR program is being conducted to compare clinical outcomes, adherence to the technology and the cost-benefit ratio.¹³ The preliminary results already show high usage rates and acceptance of the CAP model by participants. The participant's average usage rate of the mobile phone was between 91.5% and 97%, depending on the health variable that was

measured. The patients reported that the mobile phone was easy to use. 91% of the participants found the phone consultations with the mentors motivating and helpful to reach their goals.

Piotrowicz *et al.*^{14,15} assessed ECG's recorded during home-based CR for 75 stable patients with heart failure. In the 8-week programme a mini device recorded ECG's automatically at preset moments that were coordinated with exercise training. The mini device also had a tele-event-Holter ECG feature that enabled the patient to register an ECG recording immediately whenever a worrying symptom occurred. These fragments were then transmitted via mobile phone to a monitoring centre. Following the 8-week exercise training programme, the mean (SD) peak VO₂ in cardiopulmonary exercise treadmill test increased from 17.8 ml/kg/min (4.1) to 19.7 ml/kg/min (5.2) ($P < 0.0001$). The distance in the 6-min walking test increased from 418 m (92) to 462 m (91), ($P < 0.0001$). In all, 11,534 ECG fragments were transmitted and evaluated. Most ECG fragments originated from the automatic recordings, but 20 ECG fragments were recorded by 8 patients when they felt unwell. The heart failure patients undergoing the home-based telemonitored CR did not develop any arrhythmia which required a change of the procedure, confirming it was safe. Piotrowicz *et al.* concluded that CR at home can be improved when patients used the tele-event-Holter ECG facility.

Guiraud *et al.*¹⁶ explored the efficacy of telephone support guided by accelerometer measurements, on the adherence to physical activity (PA) recommendations in cardiac patients not achieving PA recommendations. In this prospective randomised study stable non-compliant cardiac patients were randomised into an intervention group and a control group. The intervention included PA recording for 8 weeks with an accelerometer and regular telephone calls by the kinesiologist to give feedback on the amount of PA performed and to provide strategies to increase the daily amount of PA. The researchers¹⁶ found that this intervention appeared to be effective to improve adherence to PA in non-compliant cardiac patients. In the intervention group, the mean (SD) time spent at moderate-intensity PA increased from 95.6 (80.7) to 137.2 (87.5) min per week between the 1st and 8th week ($P=0.002$), with 36.8 % of the sample achieving the target amount of moderate-intensity PA. During the 8th week, the active energy expenditure averaged 543.7 (144.1) kcal and 266.7 (107.4) kcal in the intervention group and control group, respectively ($P=0.004$). Reid *et al.*¹⁷ compared the CardioFit internet-based expert system with usual CR to assess its effects on PA following hospitalisation for acute coronary syndromes. A total of 223 participants were recruited for this RCT. The patients randomised to the CardioFit group had access to a secure website for activity planning and tracking (PA was measured by a pedometer). Usual care consists of PA guidance from the cardiologist. They noticed that patients in the CardioFit group were more physically active at 6 months as well as at the 12 month follow-up. At 6 months follow-up the mean (SD) amount of moderate and vigorous PA (min/week) for the patients from the CardioFit group was 201.0 (153.2),

compared to 163.4 (151.3) for the patients from the usual care group. At 12 months follow-up 201.4 (179.8) and 169.6 (152.6) min/week of moderate and vigorous PA were recorded for the CardioFit and usual care group, respectively. This translated in an increased health-related quality of life (QOL) measured by the MacNew instrument¹⁷ at 6 and 12 months of follow-up. Körtke *et al.*¹⁸ came to the same conclusion for patients that had undergone cardiac surgery such as bypass surgery, valve replacement, valve reconstruction and aortic aneurysm surgery.

The telerehab II trial (currently conducted in the Jessa Hospital, Belgium) is aiming to evaluate whether the addition of a motion sensor with automated feedback by email or SMS to the conventional rehabilitation program could result in an increase in daily activity among coronary artery disease patients. It investigates the impact of the intervention with the motion sensor on the patient's VO₂ peak (measured during ergometry), haemoglobin A1C and lipid profile as well as the feasibility of the telerehabilitation program.

A total of 80 patients are participating in the trial. They are monitored during a period of 18 weeks. Preliminary results already show a significant increase in daily activity and VO₂ peak between week 1 and week 6 as compared to conventional CR alone. In the intervention group, the daily steps increased with 94.55 % and the VO₂ peak increased with 13.09 % from week 1 to week 6. In the control group, the daily steps increased with 14.08 % and the VO₂

peak increased with 7.55 % from week 1 to week 6. Analysis of patient data after 18 weeks in the program and program results will be available soon.

Conclusion

Recent findings documented in literature suggest that telerehabilitation programs can overcome the barriers of hospital-based CR programs. Evidence is already mounting that telemedicine can be more effective than conventional CR in improving patient's physical activity level and QOL.

However, further research is required to determine the impact of a telerehabilitation intervention on patient's fitness (for example VO₂ peak, ventilatory threshold), physical activity level, rehospitalisation rate and mortality in the long-term.

Also, the value of a telerehabilitation program including other core components of CR such as nutritional counselling and psychosocial management needs to be studied.

Even though different telemedicine designs have been developed, it still needs to be determined what type of sensor/web application is most feasible for today's cardiac patient and considering the characteristics of a perfect cardiac patient training companion described in,¹¹ further sensor research and development is needed.

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