Telemonitored exercise-based cardiac rehabilitation improves physical capacity and health-related quality of life

Laustsen, Sussie; Oestergaard, Lisa G; van Tulder, Maurits; Hjortdal, Vibeke E; Petersen, Annemette K

published in
Journal of Telemedicine and Telecare
2020

DOI (link to publisher)
10.1177/1357633X18792808

document version
Publisher's PDF, also known as Version of record

Journal of Telemedicine and Telecare
2020, Vol. 26(1–2) 36–44

DOI: 10.1177/1357633X18792808
journals.sagepub.com/home/jtt
SAGE

Telemonitored exercise-based cardiac rehabilitation improves physical capacity and health-related quality of life

Sussie Laustsen[1,2], Lisa G Oestergaard[2,3,4], Maurits van Tulder[3,5], Vibeke E Hjortdal[1] and Annemette K Petersen[2,3]

Abstract

Introduction: Cardiac rehabilitation improves physical capacity, health-related quality of life, and reduces morbidity and mortality among cardiac patients. Telemonitored exercise-based cardiac rehabilitation may innovate existing programmes and increase participation rates.

Objective: The purpose of this study was to investigate if telemonitored exercise-based cardiac rehabilitation improves physical capacity, muscle endurance, muscle power, muscle strength and health-related quality of life in cardiac patients.

Methods: A follow-up study on moderate risk patients with ischaemic heart and heart valve disease referred to a 12-week telemonitored exercise-based cardiac rehabilitation intervention at Aarhus University Hospital (Denmark). Participants were encouraged to exercise 60 min three times weekly with moderate/high intensity for 20 min per session. Intensity and duration of training sessions were visualised on a smartphone and uploaded to a website. Participants received individual feedback from physiotherapists on their training efforts by telephone/email. Outcome measures were changes in physical capacity (peak oxygen uptake), muscle endurance, power, and strength, and health-related quality of life between baseline end of telemonitored exercise-based cardiac rehabilitation intervention, and at six and 12 months after end of telemonitored exercise-based cardiac rehabilitation.

Results: Thirty-four participants completed telemonitored exercise-based cardiac rehabilitation. We identified a significant increase in peak oxygen uptake of 10%, in muscle endurance of 17%, in muscle power of 7%, and in muscle strength of 10% after the telemonitored exercise-based cardiac rehabilitation programme. Health-related quality of life was significantly improved by 19% in the physical and 17% in the mental component scores. We found no significant improvement in peak oxygen uptake between baseline and 12 months follow-up, but a significant improvement in muscle endurance (0.3 watts/kg, 95% confidence interval; 0.2–0.4), muscle power (0.4 watts/kg; 0.2–0.5), muscle strength (0.5 N/m/kg; 0.1–0.9), physical health-related quality of life (five points; 2–8) and mental health-related quality of life (six points; 3–9).

Discussion: This study demonstrated that the self-elected type of physical exercise in cardiac rehabilitation with telemonitoring improved all outcome measures both on the short and long-term, except for peak oxygen uptake at 12 months follow-up.

Keywords

Cardiac rehabilitation, telehealth, muscle strength, telemedicine, telemonitoring

Date received: 10 April 2018; Date accepted: 10 July 2018

Introduction

Cardiac rehabilitation (CR) is a multidisciplinary intervention offered to patients following treatment for cardiac disease to aid recovery and prevent cardiac recurrence. CR is usually provided through group-based programmes in-hospital and includes physical exercise, education on cardio-protective lifestyle and medical evaluation.[1] Physical exercise is an essential component of CR.[2] CR reduces cardiovascular morbidity, mortality and risk of re-admission. It improves physical capacity and health-related quality of life (HRQoL).[3–5] Participation by patients in CR is challenged by work-related and social

[1]Department of Cardiothoracic and Vascular Surgery, Aarhus University Hospital, Denmark
[2]Department of Clinical Medicine, Aarhus University, Denmark
[3]Department of Physiotherapy and Occupational Therapy, Aarhus University Hospital, Denmark
[4]Department of Public Health, Aarhus University, Denmark
[5]Department of Health Sciences, Vrije Universiteit Amsterdam, The Netherlands

Corresponding author:
Sussie Laustsen, Department of Cardiothoracic and Vascular Surgery, Aarhus University Hospital, Palle Juul-Jensens Boulevard 99, 8200 Aarhus N, Denmark.
Email: slaustsen@me.com

obligations.[6] A way to improve participation rates is to offer a schedule, place and modality which are well accepted by patients. This challenge may be met by transferring CR to the patient's home using technology to monitor their lifestyle and health condition.[7,8] Telemonitored exercise-based CR (TCR) offers monitoring and the support of home-based physiotherapy. It can be an adaptable, accessible and attractive method for enabling patients to rapidly return to work. TCR improves attendance to CR,[9] decreases costs[10] and increases self-management skills,[11] leading to long-term benefits through continued exercise-based activity.[12]

Three systematic reviews point out that TCR and hospital-based CR have similar benefits on cardiovascular risk factors and reduced morbidity.[13–15] TCR seems to have similar, or even better, short-term effects on physical capacity and HRQoL compared with hospital-based CR.[7–9,12,16] Moreover, it has been shown that TCR improves patients' cardio-protective lifestyle[15,17,18] and prevents 50% of re-hospitalisations compared with usual CR.[16]

Earlier studies report diversity in the length and variety of TCR interventions, and currently there are no studies beyond 3–4 months follow-up.[17,19,20]

Increased muscle endurance, muscle power and muscle strength can improve functional capacity and HRQoL, as well as reduce comorbidity in cardiac patients.[21] To our knowledge, no TCR studies have included muscle power and muscle strength as outcome measures. Concerning HRQoL, the literature on TCR shows diversity in the use of instruments and in results.[14]

The aim of this study was to evaluate changes in physical capacity, muscle endurance, muscle power, muscle strength and HRQoL in cardiac patients following a TCR programme.

Methods

In a follow-up study, patients at moderate risk undergoing coronary artery bypass grafting, left heart valve surgery or percutaneous coronary intervention referred to CR at Aarhus University Hospital, Denmark, from April 2014–July 2015 were assessed for eligibility. Inclusion criteria were home access to the Internet, familiarity with using a smartphone, and ability to speak/read Danish. Participants with left ventricular ejection fraction $<45\%$ or having risk of anxiety (score $\geqslant 8$) and depression (score $\geqslant 8$) using the Hospital Anxiety and Depressions Scale[22] were excluded. Other exclusion criteria are shown in Figure 1.

Conventional CR

Conventional CR was provided three times weekly for 12 weeks, consisting of group-based exercise training supervised by hospital physiotherapists. Training sessions were based on current recommendations.[23,24] CR included group-based education sessions on cardio-protective lifestyle.[1] The sessions consisted of six hours; four hours with a nurse, one hour with a physiotherapist and one hour with a dietician.

TCR intervention

Patients were invited to TCR 2–6 weeks after hospital discharge, depending on treatment and diagnosis. TCR consisted of exercise training three times weekly for 12 weeks.

Initial assessment was made in two consultations at the hospital. At the first consultation, participants received basic information on how exercise impacts on their disease and health. Participants set their own goals and chose their own exercise mode i.e. running, road biking, spinning or going to the local fitness centre. To ascertain safety, establish a baseline fitness level, and determine maximal heart rate (HR_{max}), participants underwent a cardiopulmonary exercise test (V_{O2peak}). The participants' resting heart rate ($HR_{resting}$) and HR_{max} from V_{O2peak} were used to calculate the reserve heart rate ($HR_{reserve}$).[25–27]

$$HR_{reserve} = HR_{max} - HR_{resting}$$

Muscle endurance was measured during this test.

Participants were encouraged to exercise for at least 60 min, with 20 min of moderate to high intensity exercise in each session. Following recommendations, participants were instructed to exercise for 20 min per session with a moderate intensity between 40–60% of $HR_{reserve}$ during the first four weeks, and for 20 min per session with a high intensity of 60–84% of $HR_{reserve}$ during the last eight weeks.[23] At the second consultation, muscle power and muscle strength were tested. Instructions in muscle strength exercises were given. Muscle training was not telemonitored. The telemonitoring equipment was demonstrated and handed out, and participants were guided individually on exercise intensity. In the case of technical problems, the participants could obtain support within 24 h.

Three experienced physiotherapists gave individual weekly feedback on exercise training intensity by e-mail, Skype, phone or short message service (SMS) according to patient preferences. After ending TCR, participants were encouraged to continue the exercise without the monitoring equipment.

Participants were offered conventional in-hospital group-based education sessions on cardio-protective lifestyle.[1] All participants deselected these group sessions.

Technology

Participants were provided with a smartphone (Sony Xperia, Sony Mobile Communication AB, Lund, Sweden), an application (SportsMedicin) and a heart rate (HR) monitor (Zephyr BioHarness™ 3, Zephyr Technology Corp., Annapolis, USA). The system chosen was a patient-to-mobile health technology.[28] The application displayed the HR on the smartphone, and data were

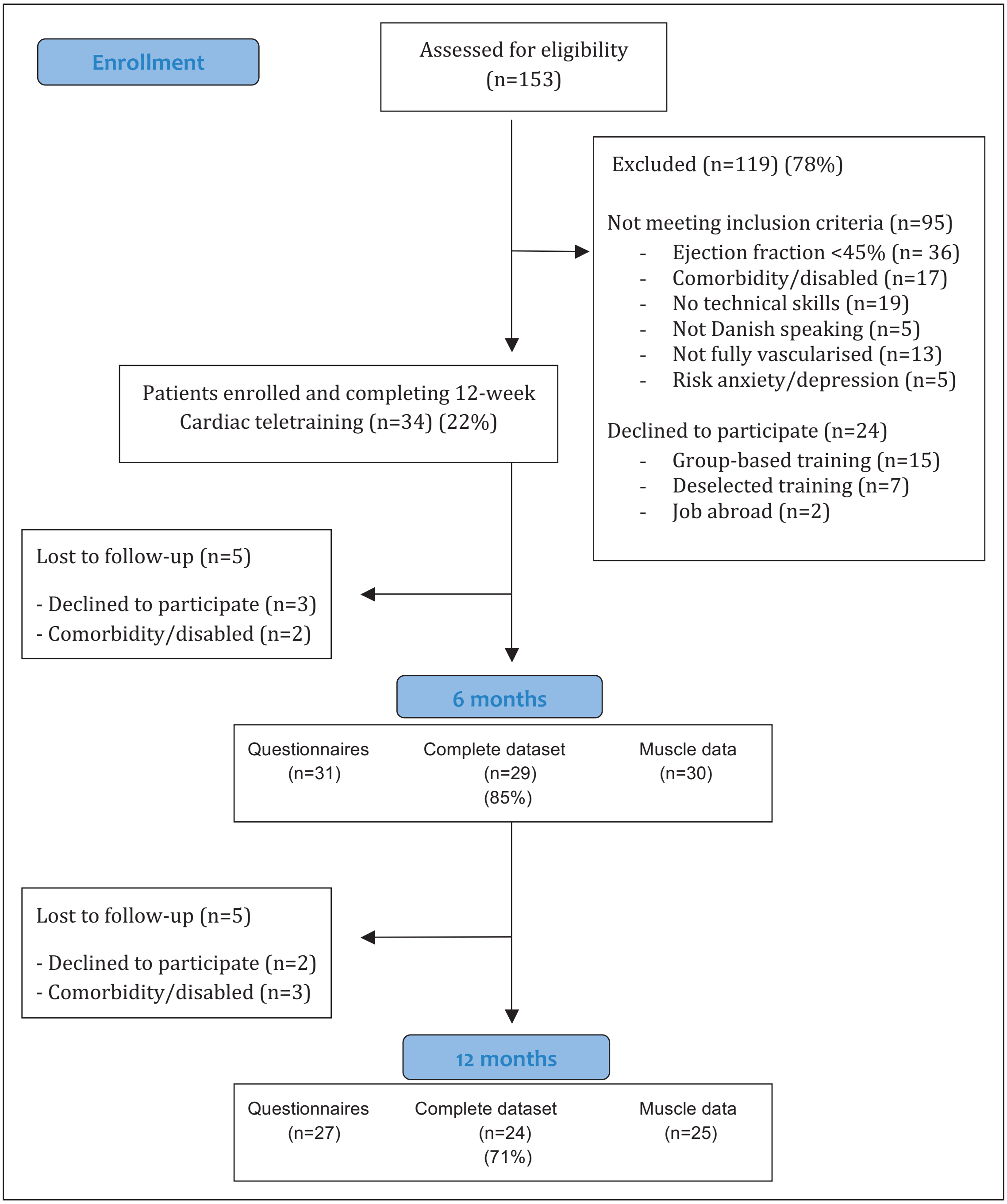

Figure 1. Flowchart of participants receiving telemonitored exercise-based cardiac rehabilitation.

uploaded via Bluetooth to a website. Based on the patient's $HR_{reserve}$, three coloured zones were displayed; low, moderate and high intensity obtained during each exercise session. The application included an alarm indicating training intensity (too low/high). Information on type of exercise could be added to the website by the patient or the physiotherapists.

Outcome assessment

Demographic and clinical characteristics were collected at baseline from medical records and patient interviews. The participants were tested before and after the 12-week TCR programme (short-term), and at six and 12 months after completing the TCR programme (long-term).

V_{O2peak}. We measured changes in physical capacity (V_{O2peak}) and muscle endurance (maximal workload in watts). V_{O2peak} reflects the body's maximal capacity to produce energy via aerobic metabolism, and is the gold standard for measuring physical capacity. V_{O2peak} is expressed and indexed to body weight as ml O_2/kg/min.[26]

The test was performed on an ergometer cycle (Lode Corival, Groningen, The Netherlands). Pulmonary ventilation and gas exchange were simultaneously measured breath-by-breath with Jaeger MasterScreen CPX

(CareFusion, San Diego, USA) and automatically calibrated. An individual workload protocol was chosen based on weight, gender and exercise habits. The test time was between 8–12 min. The participants were instructed to maintain a cadence of 60–70 rev/min, and not to talk/stand up in the pedals during testing. We used a gradually incremented test protocol with increases varying from 2 watts/6 s to 4 watts/8 s. During the test, we measured HR, blood pressure, continuous electrocardiogram, and participants were encouraged to ensure complete exhaustion. The test was considered valid when oxygen uptake or HR was levelling off.

Muscle power. Leg extension power was measured on the dominant side with Nottingham Leg Extensor Power Rig. The test was performed with the torso in an upright position, arms folded across the chest, and the test leg on a push pedal. Participants were instructed to push the pedal as forcefully and quickly as possible. Data was digitised into watts registered and stored on a personal computer (PC) with Nottingham Leg Extensor Power Rig Software. Measurements were repeated until an attempt was followed by two attempts with the same or lower value.[29]

Isometric muscle strength. Measured with maximal knee extension on the dominant side (Good Muscle Strength, Metitur). Data was digitised into N/m/kg with the Metitur software program. The highest value of five was registered.[30]

HRQoL. The validated Danish version of the Short Form-36 (SF-36) questionnaire was applied to assess HRQoL.[31,32] The questionnaire contains eight subscales and two component scores; a physical component score based on physical functioning, role-physical, bodily pain and general health; a mental component score based on vitality, social functioning, role-emotional, and mental health.

Ethics

Participants were informed about the study in an outpatient consultation prior to starting the TCR intervention. Written informed consent was obtained. The study was approved by the Central Denmark Region Committee on Health Research Ethics (ID: 1-16-02-287-14), and the Danish Data Protection Agency (j.nr. 2007-58-0010).

Statistics

Descriptive statistics were used to describe the participants' demographic and clinical characteristics. Differences among participants concerning outcome measures were analysed in a mixed effect model for repeated measurement (analysis of variance [ANOVA]) taking into account different random variations over time. STATA 15.0 (StataCort, College Station, Texas, USA) software was used.

Results

During the study period, 153 patients were referred to in-hospital CR; 119 patients (78%) did not meet the inclusion criteria (Figure 1). In total 34 (22%) patients were enrolled and completed the 12-week TCR programme. Table 1 shows demographic and clinical characteristics. No participants had angina pectoris or any complications during TCR; 20 minor technical equipment problems occurred; but did not influence on the participants exercise training.

The 34 participants had a mean of 32 training sessions (standard variation [SD] 6; range [14–36]). The mean number of hours of contact with the participants was 15 (SD 1.7). Four hours covered the two outpatient consultations at the hospital including testing; the remaining time was used for remote contact on instructing and advising.

Five participants were lost to follow-up at six months. An additional five patients were lost to follow-up at 12 months, leaving 24 participants (71%) with complete data (Figure 1).

Efficacy of the 12-week TCR

Baseline V_{O2peak} was 28.0 ml O_2/kg/min (95% confidence interval (CI) 27.4–29.0); muscle endurance was 2.3 watts/kg (95% CI 2.2–2.31); muscle power was 2.8 watts/kg (95% CI 2.7–2.9), and muscle strength was 6.8 N/m/kg (95% CI 6.5–7.0) (Table 2).

We identified a significant increase in V_{O2peak} of 10%, in muscle endurance of 17%, in muscle power of 7% and in muscle strength of 10% after the TCR programme (Table 2). HRQoL was significantly improved by 19% in the physical and 17% in the mental component scores (Table 3).

Efficacy of TCR at follow-up

The increase in V_{O2peak} was statistically significant at six months (6%), but not at 12 months follow-up (Table 2). Muscle endurance was statistically significantly improved at six (17%) and 12 months follow-up (13%); this was also seen for muscle power with 7% at six months and 14% at 12 months follow-up, and muscle strength with 15% at six and 7% at 12 months follow-up. Physical HRQoL was significantly improved with 14% at six and 12% at 12 months follow-up compared with baseline; for the mental HRQoL with 11% and 13% at six and 12 months follow-up, respectively (Table 3).

Discussion

Our results showed that a 12-week TCR programme significantly improved physical capacity, muscle endurance, muscle strength and power, and HRQoL in patients with different cardiac diagnoses. Self-selected types of physical exercise with appropriate telemonitoring improved all outcome measures both in the short and long-term, except for V_{O2peak} at 12 months follow-up.

Table 1. Baseline demographic and clinical characteristics of participants completing a 12-week telemonitored exercise-based cardiac rehabilitation programme from April 2014–July 2015.

n = 34	Cardiac patients
Age mean (SD)	58 (10.2)
Range	(25–72)
Sex (%)	
Male	28 (82.4)
Female	6 (17.7)
BMI, mean (SD)	27.1 (4.6)
Range	(20–39)
Marital status (%)	
Living alone	8 (23.5)
Partnered	26 (76.5)
Smoking (%)	
Smoker	4 (11.8)
Non-smoker	22 (64.7)
Ex-smoker	8 (23.5)
Education (%)	
Unskilled	4 (11.8)
Short (1–3 year)	9 (26.5)
Medium (3–4)	8 (23.5)
Higher (>4 year)	13 (38.2)
Work status (%)	
Working	24 (70.5)
Sick leave	5 (14.7)
Unemployed	-
Pensioner	5 (14.7)
Diagnosis (%)	
Myocardial infarction	1 (2.9)
Aortic insufficiency	8 (23.5)
Myocardial ischaemia	25 (73.5)
Treatment (%)	
Heart valve	8 (23.5)
CABG	1 (2.9)
PCI	25 (73.5)
Comorbidity (%)	
Hypertension	13 (38.2)
Claudication	1 (2.9)
Cancer	1 (2.9)
Diabetes mellitus	1 (2.9)
Beta blockers (%)	20 (58.8)
Rest heart rate mean (SD)	58 (10)
Heart rate (range)	(40–79)

ASD: atrial septal defect; BMI: body mass index; CABG: coronary artery bypass grafting; PCI: percutaneous coronary intervention; SD: standard deviation; Valve: heart valve surgery.

Efficacy of physical capacity and muscle endurance

V_{O2peak} was significantly increased by 10% and muscle endurance by 17% after the 12-week TCR. This is confirmed by another study reporting a 14% increase in V_{O2peak} and 11% in muscle endurance.[7]

We found a V_{O2peak} increase of 6% from baseline to six-month follow-up. A randomised controlled trial (RCT) found almost the same for a group participating in a 24-week TCR + usual CR.[19] The group participating in TCR increased V_{O2peak} with 1 ml O_2/kg/min, equal to a 4% increase. In this study, TCR focused on leisure-time physical activity and not physical exercise training, which may explain their lower increase in V_{O2peak}.[19]

It is reported that one metabolic equivalent (MET) ~3.5 ml O_2/kg/min increase in physical capacity can be transformed to a 12% improvement in survival prognosis in persons with cardiovascular disease.[33] Our participants did not attain one MET following TCR (2.8 ml O_2/kg/min), and an even lower improvement was found at six months follow-up. This indicates that participants did not continue their exercise habits and did not achieve a sustainable active lifestyle, and thus decreased their chance of survival. This is also reported in other studies.[19,34]

Muscle power and strength

The participants increased their muscle strength and power significantly at all time-points. To our knowledge, we are the first to evaluate improvement in muscle parameters caused by TCR. Guidelines recommend dynamic resistance exercise-training interventions, as they are safe, reduce blood pressure, and induce vascular adaptations.[35,36] Furthermore, increased muscle power and strength can improve functional capacity, bone mineral density, insulin resistance, endothelial function and HRQoL, as well as reduce the risk of falls in elderly people.[21] Our results are thus important, since the increased muscle strength and power may be cardio-protective and hence improve prognosis. Further studies are needed to investigate the effects of resistance training interventions in TCR.

HRQoL

Physical and mental HRQoL were significantly improved at all time-points. Other TCR studies using SF-36 showed a significant improvement over time in the physical component score, but not in the mental component score.[15] Maddison et al. reported in 2015 on a RCT comparing TCR with usual CR and found a lower increase in HRQoL in the TCR group than we did in our study. Their telemonitored intervention was an automated package with text messages and a website with videos.[19] Our TCR intervention was an application with live display of exercise data automatically being uploaded to a website. Furthermore, the experienced physiotherapists encouraged participants by providing feedback, and participants also had the opportunity to discuss other concerns by phone or email. This occurred frequently, but we did not register specifically how often. The opportunity to discuss worries may impact on increased HRQoL. Anxiety and depression were exclusion criteria in our study, and thus mental HRQoL was probably not affected in our population. Therefore, it was surprising that our participants improved in the assessment of mental HRQoL.

Table 2. Data on physical capacity outcome measures at baseline, end of intervention, six and 12 months after end of intervention, in 34 patients completing a 12-week telemonitored exercise-based cardiac rehabilitation programme (TCR). Data are presented as mean with 95% confidence intervals (CIs) and analysed in a mixed effect repeated measurement model.

	Start TCR Mean (95% CI) $n = 34$	End TCR Mean (95% CI) $n = 34$	Difference End vs start TCR mean (95% CI)	6 months Mean (95% CI) $n = 29$	Difference 6-Month vs start mean (95% CI)	12 months Mean (95% CI) $n = 24$	Difference 12-Month vs start mean (95% CI)
V_{O2peak}							
Ml O_2/min/kg	28.0 (27.4–29.0)	31.0 (30.2–31.8)	2.8 (1.7–3.9) $p = 0.000$	30.0 (29.2–30.9)	1.8 (0.7–3.0) $p = 0.002$	28.7 (27.7–29.7)	0.6 (–0.7–1.8) $p = 0.372$
Muscle endurance							
Watts/kg	2.3 (2.2–2.31)	2.6 (2.5–2.7)	0.4 (0.3–0.44) $p = 0.000$	2.64 (2.57–2.7)	0.4 (0.3–0.5) $p = 0.000$	2.57 (2.49–2.64)	0.3 (0.2–0.4) $p = 0.000$
Muscle power[a]							
Watts/kg	2.8 (2.7–2.9)	3.0 (2.9–3.1)	0.2 (0.03–0.3) $p = 0.014$	3.0 (2.9–3.1)	0.2 (0.01–0.3) $p = 0.036$	3.2 (3.1–3.3)	0.4 (0.2–0.5) $p = 0.000$
Muscle strength[a]							
N/m/kg	6.8 (6.5–7.0)	7.4 (7.2–7.7)	0.7 (0.4–1.0) $p = 0.000$	7.7 (7.5–8.0)	1.0 (0.6–1.4) $p = 0.000$	7.2 (7.0–7.5)	0.5 (0.1–0.9) $p = 0.011$

[a]Muscle data at six months follow-up $n = 30$, at 12 months follow-up $n = 25$.

Table 3. Data on mental and physical HRQoL (SF-36) at baseline, end of intervention, six and 12 months after end of intervention, in 34 patients completing a 12-week telemonitored exercise-based cardiac rehabilitation programme (TCR). Data are presented as mean with 95% confidence intervals (CIs) and analysed in a mixed effect repeated measurement model.

	Start TCR Mean (95% CI) $n = 34$	End TCR Mean (95% CI) $n = 34$	Difference End vs start mean (95% CI)	6 months Mean (95% CI) $n = 31$	Difference 6-Month vs start mean (95% CI)	12 months Mean (95% CI) $n = 27$	Difference 12-Month vs start mean (95% CI)
Physical component scale (PCS)	43 (42–45)	51 (49–53)	8 (5–10) $p = 0.000$	49 (48–51)	6 (3–9) $p = 0.000$	48 (46–50)	5 (2–8) $p = 0.001$
Physical functioning	78 (75–81)	89 (87–92)	11 (7–15) $p = 0.000$	85 (82–88)	7 (3–11) $p = 0.002$	86 (83–90)	8 (4–13) $p = 0.001$
Role-physical	33 (24–43)	87 (78–96)	54 (41–67) $p = 0.000$	76 (67–86)	43 (30–56) $p = 0.000$	70 (59–81)	37 (22–51) $p = 0.000$
Bodily pain	63 (57–69)	80 (74–86)	17 (9–26) $p = 0.000$	78 (72–84)	15 (6–23) $p = 0.001$	76 (69–83)	13 (3–22) $p = 0.008$
General health	67 (64–71)	75 (71–78)	8 (3–13) $p = 0.003$	73 (69–77)	6 (0.7–11) $p = 0.027$	70 (66–74)	3 (–3–8) $p = 0.290$
Mental component scale (MCS)	47 (45–49)	55 (53–57)	8 (6–11) $p = 0.000$	52 (50–54)	5 (2–9) $p = 0.000$	53 (51–56)	6 (3–9) $p = 0.000$
Vitality	50 (46–54)	71 (68–75)	21 (13–27) $p = 0.000$	64 (60–67)	14 (8–19) $p = 0.000$	66 (62–71)	16 (11–22) $p = 0.000$
Social functioning	80 (75–84)	94 (89–98)	14 (7–20) $p = 0.000$	88 (83–93)	8 (1–15) $p = 0.017$	90 (84–95)	10 (3–17) $p = 0.008$
Role-emotional	54 (45–63)	87 (78–96)	33 (21–46) $p = 0.000$	80 (71–89)	26 (14–39) $p = 0.000$	84 (73–94)	30 (16–44) $p = 0.000$
Mental health	72 (68–75)	86 (82–89)	14 (9–19) $p = 0.000$	81 (78–85)	10 (4–15) $p = 0.000$	81 (77–85)	9 (4–15) $p = 0.001$

Kraal et al., in 2014, also found that HRQoL was improved with 13% in the physical component score and 4% in the mental component score.[7] However, in the study by Kraal et al. they used a disease specific MacNew questionnaire, which may explain this observed difference.

Feasibility

There were no cardiac-related serious events during the TCR; the literature is inconsistent about safety in TCR programmes.[17,19] In a RCT on TCR ($n = 85$), 15 cardiac-related events were reported.[19] Our participants were highly selected, and the study population was too small to measure safety, which may explain the difference in our results.

Even though we did not ask participants to give feedback on the telemonitoring equipment, the participants only contacted the physiotherapists about minor technical problems. This is equivalent to another study where 83% of participants provided overall positive feedback on the TCR equipment.[37]

All 34 participants completed the TCR programme, and the number of sessions was 89%. This corresponds to results in other studies.[38] Even smaller studies ($n = 26$) have shown that the use of telemonitoring equipment could improve adherence to CR programmes once enrolled. Forman et al., in 2014, described a 42% reduction in cancellations with a coaching application on physical activity compared with conventional CR. In this study 70% of participants complied with physical activity three days per week.[37] This was similar to a RCT comparing a telemonitored intervention group with standard CR.[17] We have previously reported compliance with conventional CR to be below 50%.[6] The lower adherence described in other TCRs and conventional CR programmes compared with adherence in our study may be due to the study population being selected and not comparable with the overall up-take in CR programmes. Our participants rejected the in-hospital educational sessions despite being motivated to participate. Most participants deselected this because they did not want to travel to the hospital.

The strength of TCR is that physical exercise can be done wherever and whenever the patient chooses. It facilitates regular communication, and messages can be delivered in a time-sensitive and time-applicable manner. Additionally, participants are not required to attend the hospital regularly. In this way TCR has the ability to be well-integrated into daily life.[17] Our TCR showed the continuous status of exercise capacity from participants' living environment. This may be more useful than conventional in-hospital CR.[39]

Limitations

We had no control group. Thus, it is unknown if the participants would benefit equally by not attending TCR or by receiving conventional CR. However, TCR is known to be as efficient as conventional CR.[7] Only 22% of eligible patients participated in the study, a selection problem limiting the external validity. So far, TCR has proven useful in our participants and further studies are needed to investigate if this intervention could benefit participants at higher risk.

It is unknown why the improvement in V_{O2peak} was not sustained beyond the six-month follow-up. Participants may not have continued exercising after the TCR period, but we did not measure this. In future studies, it is relevant to use a questionnaire such as the International Physical Activity Questionnaire[40] during follow-up.

Another weakness was that muscle training was not telemonitored. Telemonitoring of number of repetitions and weight load could be part of future TCR studies.

Conclusion

This study demonstrated that the TCR programme significantly improved physical capacity following a 12-week intervention, but no improvement was found beyond the six-month follow-up, probably because participants did not maintain their exercise level. TCR increased participants' muscle endurance, strength, power as well as HRQoL both in the short-term and long-term. Our results indicate the suitability of delivering TCR to participants with different cardiac diseases in their self-imposed environment. The effectiveness and cost-effectiveness of TCR should be evaluated in future studies.

Acknowledgements

The authors wish to express their thanks to Marie V Knudsen for data collection, to Maria K Skou, Dagmar L Sieg and Camilla Pedersen for the physiotherapy-led intervention, to Marianne G Hansen for English language support, and for statistical advice from BIAS Core Facility, Aarhus University. All authors made a substantial contribution to conceptualising this work, have participated sufficiently to take public responsibility for appropriate portions of the content, and have approved the version to be published. The design of the work, acquisition, analysis and interpretation of data were performed by SL and AKP. SL drafted the article, and all co-authors have revised it critically for important intellectual content. Data are placed behind an encrypted firewall at the Hospital. According to Danish law, personalised data are not allowed outside this premises. Data are accessible only through first and last authors personal log-on at the hospitals secure server.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the NOVO Nordic Research Foundation (NNF13OC0002767), The Spearhead Fund, Aarhus University Hospital (DK), the National Funds for Chronic Diseases (DK), and the Research Foundation, Aarhus University Hospital (DK).

ORCID iDs

Sussie Laustsen http://orcid.org/0000-0003-0560-0606
Maurits van Tulder http://orcid.org/0000-0002-7589-8471

References

1. Piepoli MF, Corra U, Benzer W, et al. Secondary prevention through cardiac rehabilitation: From knowledge to implementation. A position paper from the Cardiac Rehabilitation Section of the European Association of

Cardiovascular Prevention and Rehabilitation. *Eur J Cardiovasc Prev Rehabil* 2010; 17: 1–17.
2. Pavy B, Iliou MC, Meurin P, et al. Safety of exercise training for cardiac patients: Results of the French registry of complications during cardiac rehabilitation. *Arch Intern Med* 2006; 166: 2329–2334.
3. Anderson L, Oldridge N, Thompson DR, et al. Exercise-based cardiac rehabilitation for coronary heart disease: Cochrane systematic review and meta-analysis. *J Am Coll Cardiol* 2016; 67: 1–12.
4. Anderson L and Taylor RS. Cardiac rehabilitation for people with heart disease: An overview of Cochrane systematic reviews. *Cochrane Database Syst Rev* 2014; 12: CD011273.
5. Heran BS, Chen JM, Ebrahim S, et al. Exercise-based cardiac rehabilitation for coronary heart disease. *Cochrane Database Syst Rev* 2011; 7: CD001800.
6. Laustsen S, Hjortdal VE and Petersen AK. Predictors for not completing exercise-based rehabilitation following cardiac surgery. *Scan Cardiovasc J* 2013; 47: 344–351.
7. Kraal JJ, Peek N, Van den Akker-Van Marle ME, et al. Effects of home-based training with telemonitoring guidance in low to moderate risk patients entering cardiac rehabilitation: Short-term results of the FIT@Home study. *Eur J Prev Cardiol* 2014; 21: 26–31.
8. Piotrowicz E, Zielinski T, Bodalski R, et al. Home-based telemonitored Nordic walking training is well accepted, safe, effective and has high adherence among heart failure patients, including those with cardiovascular implantable electronic devices: A randomised controlled study. *Eur J Prev Cardiol* 2015; 22: 1368–1377.
9. Varnfield M, Karunanithi M, Lee CK, et al. Smartphone-based home care model improved use of cardiac rehabilitation in postmyocardial infarction patients: Results from a randomised controlled trial. *Heart* 2014; 100: 1770–1779.
10. Whittaker F and Wade V. The costs and benefits of technology-enabled, home-based cardiac rehabilitation measured in a randomised controlled trial. *J Telemed Telecare* 2014; 20: 419–422.
11. Kothapalli P, Bove AA, Santamore WP, et al. Factors affecting frequency of patient use of Internet-based telemedicine to manage cardiovascular disease risk. *J Telemed Telecare* 2013; 19: 205–208.
12. Reid RD, Morrin LI, Beaton LJ, et al. Randomized trial of an internet-based computer-tailored expert system for physical activity in patients with heart disease. *Eur J Prev Cardiol* 2012; 19: 1357–1364.
13. Currell R, Urquhart C, Wainwright P, et al. Telemedicine versus face to face patient care: Effects on professional practice and health care outcomes. *Cochrane Database Syst Rev* 2000; 2: CD002098.
14. Munro J, Angus N and Leslie SJ. Patient focused Internet-based approaches to cardiovascular rehabilitation – a systematic review. *J Telemed Telecare* 2013; 19: 347–353.
15. Neubeck L, Redfern J, Fernandez R, et al. Telehealth interventions for the secondary prevention of coronary heart disease: A systematic review. *Eur J Cardiovasc Prev Rehabil* 2009; 16: 281–289.
16. Woodend AK, Sherrard H, Fraser M, et al. Telehome monitoring in patients with cardiac disease who are at high risk of readmission. *Heart Lung* 2008; 37: 36–45.
17. Widmer RJ, Allison TG, Lennon R, et al. Digital health intervention during cardiac rehabilitation: A randomized controlled trial. *Am Heart J* 2017; 188: 65–72.
18. Widmer RJ, Collins NM, Collins CS, et al. Digital health interventions for the prevention of cardiovascular disease: A systematic review and meta-analysis. *Mayo Clin Proc* 2015; 90: 469–480.
19. Maddison R, Pfaeffli L, Whittaker R, et al. A mobile phone intervention increases physical activity in people with cardiovascular disease: Results from the HEART randomized controlled trial. *Eur J Prev Cardiol* 2015; 22: 701–709.
20. Widmer RJ, Allison TG, Lerman LO, et al. Digital health intervention as an adjunct to cardiac rehabilitation reduces cardiovascular risk factors and rehospitalizations. *J Cardiovasc Transl Res* 2015; 8: 283–292.
21. Pollock ML, Franklin BA, Balady GJ, et al. AHA Science Advisory. Resistance exercise in individuals with and without cardiovascular disease: Benefits, rationale, safety, and prescription: An advisory from the Committee on Exercise, Rehabilitation, and Prevention, Council on Clinical Cardiology, American Heart Association; Position paper endorsed by the American College of Sports Medicine. *Circulation* 2000; 101: 828–833.
22. Bjelland I, Dahl AA, Haug TT, et al. The validity of the Hospital Anxiety and Depression Scale. An updated literature review. *J Psychosom Res* 2002; 52: 69–77.
23. Fletcher GF, Ades PA, Kligfield P, et al. Exercise standards for testing and training: A scientific statement from the American Heart Association. *Circulation* 2013; 128: 873–934.
24. Mezzani A, Hamm LF, Jones AM, et al. Aerobic exercise intensity assessment and prescription in cardiac rehabilitation: A joint position statement of the European Association for Cardiovascular Prevention and Rehabilitation, the American Association of Cardiovascular and Pulmonary Rehabilitation and the Canadian Association of Cardiac Rehabilitation. *Eur J Prev Cardiol* 2013; 20: 442–467.
25. Fletcher GF, Balady GJ, Amsterdam EA, et al. Exercise standards for testing and training: A statement for healthcare professionals from the American Heart Association. *Circulation* 2001; 104: 1694–1740.
26. Balady GJ, Arena R, Sietsema K, et al. Clinician's Guide to cardiopulmonary exercise testing in adults: A scientific statement from the American Heart Association. *Circulation* 2010; 122: 191–225.
27. Guazzi M, Arena R, Halle M, et al. 2016 focused update: Clinical recommendations for cardiopulmonary exercise testing data assessment in specific patient populations. *Eur Heart J* 2016; 133: e694–e711.
28. Tuckson RV, Edmunds M and Hodgkins ML. Telehealth. *N Engl J Med* 2017; 377: 1585–1592.
29. Bassey EJ and Short AH. A new method for measuring power output in a single leg extension: Feasibility, reliability and validity. *Eur J Appl Physiol Occup Physiol* 1990; 60: 385–390.
30. Tiainen K, Sipila S, Kauppinen M, et al. Genetic and environmental effects on isometric muscle strength and leg extensor power followed up for three years among older female twins. *J Appl Physiol (1985)* 2009; 106: 1604–1610.
31. Bjorner JB, Damsgaard MT, Watt T, et al. Tests of data quality, scaling assumptions, and reliability of the Danish SF-36. *J Clin Epidemiol* 1998; 51: 1001–1011.
32. Bjorner JB, Thunedborg K, Kristensen TS, et al. The Danish SF-36 Health Survey: Translation and preliminary validity studies. *J Clin Epidemiol* 1998; 51: 991–999.

33. Kokkinos P and Myers J. Exercise and physical activity: Clinical outcomes and applications. *Circulation* 2010; 122: 1637–1648.
34. Frederix I, Vanhees L, Dendale P, et al. A review of telerehabilitation for cardiac patients. *J Telemed Telecare* 2015; 21: 45–53.
35. Millar PJ, McGowan CL, Cornelissen VA, et al. Evidence for the role of isometric exercise training in reducing blood pressure: Potential mechanisms and future directions. *Sports Med* 2014; 44: 345–356.
36. Guiraud T, Labrunee M, Pillard F, et al. Whole-body strength training using a Huber Motion Lab in coronary heart disease patients: Safety, tolerance, fuel selection, and energy expenditure aspects and optimization. *Am J Phys Med Rehabil* 2015; 94: 385–394.
37. Forman DE, LaFond K, Panch T, et al. Utility and efficacy of a smartphone application to enhance the learning and behavior goals of traditional cardiac rehabilitation: A feasibility study. *J Cardiopulm Rehabil Prev* 2014; 34: 327–334.
38. Weingarten MN, Salz KA, Thomas RJ, et al. Rates of enrollment for men and women referred to outpatient cardiac rehabilitation. *J Cardiopulm Rehabil Prev* 2011; 31: 217–222.
39. Bidargaddi NP and Sarela A. Activity and heart rate-based measures for outpatient cardiac rehabilitation. *Methods Inf Med* 2008; 47: 208–216.
40. Craig CL, Marshall AL, Sjostrom M, et al. International physical activity questionnaire: 12-Country reliability and validity. *Med Sci Sports Exerc* 2003; 35: 1381–1395.