European Journal of Preventive Cardiology
ESC European Society of Cardiology

Full research paper

European Journal of Preventive Cardiology
2019, Vol. 26(1) 46–55

DOI: 10.1177/2047487318791609
journals.sagepub.com/home/ejpc
SAGE

Impact of cognitive performance on disease-related knowledge six months after multi-component rehabilitation in patients after an acute cardiac event

Annett Salzwedel[1], Maria-Dorothea Heidler[1,2], Karin Meng[3], Martin Schikora[2], Karl Wegscheider[4], Rona Reibis[5] and Heinz Völler[1,6]

Abstract

Background: Although associations between cardiovascular diseases and cognitive impairment are well known, the impact of cognitive performance on the success of patient education as a core component of cardiac rehabilitation remains insufficiently investigated so far.

Design: Prospective observational study in two inpatient cardiac rehabilitation centres between September 2014 and August 2015 with a follow-up six months after cardiac rehabilitation.

Method: At admission to and discharge from cardiac rehabilitation, the cognitive performance of 401 patients (54.5 $\pm$ 6.3 years, 80% men) following an acute coronary syndrome and/or coronary artery bypass graft was tested using the Montreal Cognitive Assessment. Patients' disease-related knowledge was determined using a quiz (22 items for medical knowledge and 12 items for healthy lifestyle and behaviour) at both times and at follow-up. The change in knowledge after cardiac rehabilitation was analysed in multivariable regression models. Potentially influencing parameters (e.g. level of education, medication, cardiovascular risk factors, coronary artery bypass graft, comorbidities, exercise capacity) were considered.

Results: During cardiac rehabilitation, disease-related knowledge was significantly enhanced in both scales. At follow-up, the average level of medical knowledge was significantly reduced, while lifestyle knowledge remained at a stable level. The maintenance of knowledge after cardiac rehabilitation was predominantly predicted by prior knowledge, cognitive performance at discharge from cardiac rehabilitation and, in the case of medical knowledge, by coronary artery bypass graft.

Conclusion: Patient education in cardiac rehabilitation led to enhanced disease-related knowledge, but the maintenance of this essentially depended on patients' cognitive performance, especially after coronary artery bypass graft. Therefore, patient education concepts in cardiac rehabilitation should be reconsidered and adjusted as needed.

Keywords
Mild cognitive impairment, cardiac rehabilitation, patient education, coronary artery disease, secondary prevention

Received 4 April 2018; accepted 9 July 2018

Introduction

After an acute coronary syndrome (ACS) and/or a coronary artery bypass graft (CABG), patients should be assigned to cardiac rehabilitation (CR).[1] Multi-component centre-based CR leads to an essential reduction in major adverse cardiac and cerebrovascular events, especially in mortality.[2] In the context of the meta-analysis by Rauch et al., multi-component CR was defined as exercise training and at least one additional therapy

[1]Department of Rehabilitation Research, University of Potsdam, Germany
[2]Brandenburg Klinik Bernau, Germany
[3]Department of Medical Psychology and Psychotherapy, University of Würzburg, Germany
[4]Institute for Medical Biometry and Epidemiology, University Medical Center Hamburg-Eppendorf, Germany
[5]Cardiological Outpatient Clinic, Am Park Sanssouci, Germany
[6]Klinik am See, Rehabilitation Centre of Cardiovascular Diseases, Germany

Corresponding author:
Annett Salzwedel, Department of Rehabilitation Research, University of Potsdam, Am Neuen Palais 10, 14469 Potsdam, Germany.
Email: annett.salzwedel@uni-potsdam.de

offering, which in the included studies was most often patient education.[2]

In Germany, CR after an acute cardiovascular event usually starts within 14 days and is usually carried out in an in-patient setting with a mean duration of three weeks.[3] In accordance with national and European guidelines, the programme includes exercise training, psychological care (individual counselling by a psychologist and/or group sessions for coping) and nutritional advice, in addition to medical care.[4,5] Moreover, patient education for secondary prevention of coronary artery disease (CAD), including cardiovascular function disorders and risk factors, treatment and handling of CAD in everyday life, and necessary lifestyle changes, is an integral part of this comprehensive CR programme.[4,6] For this intensive education programme, sufficient cognitive function in patients is required.

Indeed, associations between cognitive impairment and cardiovascular diseases are well known. In a recent systematic review and meta-analysis, Cannon et al. detected a 43% prevalence of cognitive impairment in 26 studies with more than 4000 heart failure patients.[7] Another meta-analysis published in 2017 showed a high risk for cognitive dysfunction or dementia in patients with coronary heart disease.[8] Even cognitive alterations after cardiac surgery, particularly CABG, are described comprehensively.[9]

Nevertheless, the data available are rather diffuse with regard to prevalence rates, affected cognitive functions and the severity or course of cognitive impairment, in particular the reversion or conversion of the cognitive impairment into manifest dementia. Published studies are heterogeneous in terms of the investigated populations (e.g. diagnoses, case-mix, age), settings, time frames, assessments used for cognitive impairments (e.g. screening tests or neuropsychological test batteries) and, finally, the accepted definition of cognitive impairment itself.

Both heart disease and cognitive decline, e.g. dementia, are age-associated. But, a prospective cohort study published in 2012 found cognitive impairment already in middle age (45–50 years).[10] Even for populations with cardiovascular diseases, decline in cognitive performance could already be noted for the middle years of life.[11,12] However, the reported declines ‘were small and probably not clinically significant’ for younger study participants (p. 46).[11] Thus, the degree of impairments most closely correspond to the generic term of mild cognitive impairment (MCI), with the preservation of activities of daily living and social environment.[13]

Based on these findings, the prevalence rate of cognitive deterioration in CAD patients following an acute cardiac event in CR must be estimated as high even in younger patients, so that negative effects on the rehabilitation success and the patients’ education in particular are likely. The aim of the present study was to clarify the impact of cognitive performance on the success of patient education in CR patients under 65 years of age after an acute cardiac event. We hypothesised that cognitive impairment would negatively predict changes in disease-related knowledge six months after CR.

Methods

Study design and patients

We designed a prospective observational study in two in-patient rehabilitation centres with a follow-up (FU) conducted by mail six months after CR. Eligible patients were aged up to 65 years, had suffered CAD, and were assigned to CR due to an ACS and/or CABG. Patients with diagnosis dementia as documented in the patient record, insufficient German language skills or missing consent were excluded.

CR programme

Patients were enrolled between September 2014–August 2015 upon admission to CR. The conducted CR was the usual standardised, intensive, multimodal rehabilitation programme in Germany with a mean duration of three weeks, which usually begins within 14 days after discharge from hospital. This CR programme includes exercise training and sports therapy, cardiovascular risk factor management, psychological support (e.g. counselling/coping by a psychologist in single or group sessions), lifestyle adjustment and nutritional advice, as well as patient education for the secondary prevention of CAD supervised by a cardiologist and medical staff.[14,15]

The patient education programme during CR consisted of 6–10 group sessions on the topics of cardiovascular function disorder, symptoms of ACS, cardiovascular risk factors, acute therapy and medical treatment, disease and risk factor management in everyday life, and required lifestyle adjustments.[16] The sessions were conducted by physicians, dietitians, psychologists, sports therapists and physiotherapists. The education content was checked by a multi-week supervision in the CR centres and updated if necessary before the start of recruitment. Participation of the enrolled patients in the patient education programme was mandatory. Patients were informed of this during the enrolment process.

Data sources

The global cognitive performance of all enrolled patients was tested using the Montreal Cognitive

Assessment (MoCA) by trained study nurses.[17] The MoCA is a short screening assessment instrument with a high sensitivity for MCI, which was expected in the investigated population. It includes 16 items to assess multiple cognitive domains (e.g. executive function, memory, naming, language, abstraction, attention and orientation). We used the original version (German translation) at admission to CR and the alternate version at discharge from CR in order to exclude learning effects.[17–19] MCI was set for values below 26 points, with a maximum of 30 achievable points in MoCA. Patients with less than 12 formal education years received an additional point for education adjustment.

At admission to CR, we documented sociodemographic data (e.g. age, sex, educational level by years as well as graduation), lifestyle information (e.g. nutrition, physical activity (PA) >30 min in times per week, smoking, alcohol consumption), clinical parameters (e.g. cardiovascular risk factors, relevant comorbidities, left ventricular ejection fraction (LVEF), New York Heart Association (NYHA) classification of heart failure, and the intake of psychotropic drugs), and occupational data including the patients' employment status before CR. Furthermore, we determined their physical fitness using the six-minute walking test (6MWT) and exercise capacity in bicycle ergometry, respectively, and the emotional status according to the Hospital Anxiety and Depression Scale (HADS) at admission and discharge from CR.

CR outcome

In this study, we defined patients' CR outcome as changes in disease-related knowledge through patient education. For this, we used a quiz consisting of 10 multiple-choice questions with 34 items, divided into two scales.[6] The medical knowledge scale with a maximum of 22 points included items on the topics of basic information, symptoms of ACS, cardiovascular risk factors, treatment and medication. Questions on PA, nutrition or stress were summarised in the lifestyle and behavioural scale (maximum 12 points). The quiz was scored by adding up the correct answers. Missing answers were considered incorrect. It took about 15 min upon admission and discharge from CR, as well as six months after CR. The quiz was preliminarily tested for normal distribution and intelligibility in six groups with a total of 73 CR patients and was slightly modified before the study recruitment started.

The FU questionnaires contained 11 additional items regarding the patients' occupational status, rehospitalisation and current lifestyle (smoking, alcohol consumption, nutrition including soft drinks, physical activity) in order to gain further indications of the sustainability of the CR education programme. The questions were in multiple- or single-choice format (for example, 'How many times have you eaten fruits or vegetables in the last four weeks? (a) several times a day, (b) once a day, (c) less frequently') or open-answer format (for example, 'Now we come to sports activities in the last 4 weeks, such as hiking, jogging or cycling. How many days per week were you active in sports? Please count only activities that lasted at least 30 minutes each').

Ethics approval and study registration

All patients were comprehensively informed about the contents of the study and provided informed written consent before enrolment. The study was approved by the Ethics Committee of the Faculty of Human Sciences of the University of Potsdam and registered by the German Register of Clinical Trials and the International Clinical Trial Agency Platform of the World Health Organization (ICTRP, WHO; registration number DRKS00005502).

Statistics

Metric variables are presented as means ± standard deviation (SD), and categorical variables as absolute values and percentages. Differences in variables between admission to CR, discharge from CR and FU were tested for statistical significance using Wilcoxon and McNemar tests, respectively. Additionally, standardised effect size (SES) was calculated (ratio of mean value differences and pretest SD).[20] Group differences (MCI vs no MCI) were tested with the Mann-Whitney-U test. Changes in disease-related knowledge between discharge from CR and the FU were calculated as differences in quiz scores for both scales. The changes in knowledge were analysed by means of linear regression models with stepwise backwards selection to identify predictors of education success. Sex, age, body mass index, educational level, occupational situation, intake of psychotropic drugs (antidepressants, anticonvulsants, neuroleptics), CABG, comorbidities, physical fitness (6MWT, exercise capacity in bicycle ergometry), HADS scores, LVEF, MoCA values and the interaction term of MoCA by CABG were taken into account in the modelling. The effect-size estimates of the independent predictor variables are presented as Δ knowledge between CR discharge and FU with SD of knowledge at discharge as measurement unit. Thus, they can be interpreted as effect sizes like Cohen's d. The results are shown with 95% confidence intervals and p-values. Effects with a p-value of less than 0.05 were considered statistically significant. Calculations were carried out using SPSS 23.0 (IBM, Chicago, Illinois, USA).

Results

Patient characteristics and rehabilitation

Of 648 eligible patients, 521 were included in the study. Twenty-four of these dropped out prematurely due to rehospitalisation ($n = 2$), withdrawal of consent ($n = 5$), or for organisational reasons (e.g. MoCA screening not scheduled at weekend-discharge from CR; $n = 17$). 401 of 497 participants (81%) responded to the FU questionnaires and were analysed in this investigation (Figure 1).

These patients were aged 55 ± 6 years, 80% male. They were assigned to CR due to percutaneous coronary intervention (PCI) for ACS (67%) and CABG (29%). Patient characteristics, risk factors and comorbidities are presented in Table 1.

A positive screening result for MCI was detected in 142 patients (36%) at admission to CR, while 131 (33%) were affected at discharge ($p = 0.3$). No statistically significant associations with CABG were recognisable (26% patients after CABG in no MCI group vs 33% in MCI group at admission, $p = 0.13$; 26% patients after CABG in noMCI group vs 34% in MCI group at discharge from CR, $p = 0.12$). Overall, the cognitive performance in MoCA, depressive symptoms and anxiety in HADS as well as physical fitness in 6MWT and bicycle ergometry were significantly improved during CR (mean duration 20 ± 3 days; Table 2). Similarly, disease-related knowledge was increased (independent of CABG) by 2.1 and 1.0 points on both medical and lifestyle scales, corresponding to medium SES of 0.6 and 0.5, respectively. However, patients with MCI participated in fewer educational sessions, although all patients had been previously informed of the need. While most patients with normal cognitive function participated in all education sessions, in cognitively impaired patients the median was only 91% of the sessions attended (Figure 2).

Mid-term changes in disease-related knowledge and lifestyle

The FU was performed on average 211 ± 51 days after discharge from CR. During this period, patients' medical knowledge had significantly decreased by 0.4 ± 3.6 quiz points ($p = 0.03$; range of differences FU-discharge from CR: min. –15–maximum 12 quiz points, SES 0.13), wherein these changes depended on a performed CABG (Δ medical knowledge -1.04 ± 3.75 in patients after CABG vs -0.12 ± 3.49 without CABG, $p = 0.01$).

Lifestyle knowledge remained at a stable level regardless of CABG (-0.1 ± 1.9 quiz points; $p = 0.68$; range of Δ: –8–9 quiz points, SES 0.06).

At the same time, patient-reported lifestyle behaviours pointed at least partially to an

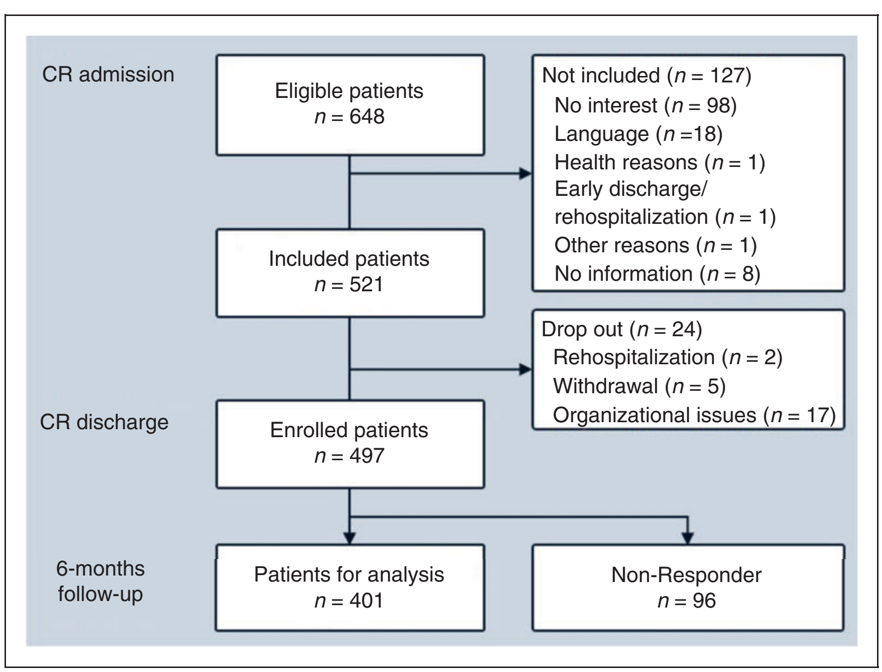

Figure 1. Flowchart of patient recruitment and study process. CR: cardiac rehabilitation.

Table 1. Baseline characteristics ($n = 401$).

Parameter	Mean ± SD or n (%)
Sociodemographic data	
Age (years)	54.5 ± 6.3
Sex (male)	321 (80.0)
BMI (kg/m^2)	28.7 ± 5.1
Education < 10 years	56 (14.0)
Occupation (employed)	341 (85.0)
ACS treatment	
PCI (%)	269 (67.1)
CABG	114 (28.4)
Conservative procedure	17 (4.2)
Cardiovascular symptoms	
LVEF (%)/<45%	55.4 ± 7.6/30 (7.5)
NYHA classification I/II/III–IV (n = 399)	291 (72.9)/96 (24.1)/12 (3.0)
Cardiovascular risk factors	
Hypertension	279 (69.6)
Diabetes mellitus	92 (22.9)
Dyslipidemia	261 (65.1)
Smoker/ex-smoker (<12 months)	228 (56.9)
Comorbidities	248 (61.8%)
COPD	30 (7.5)
Stroke	14 (3.5)
PAD	22 (5.5)
Orthopaedic disease	148 (36.9)
Mental disease	44 (11.0)
Psychotropic drug intake[a]	20 (5.0)

BMI: body mass index; CABG: coronary artery bypass graft; COPD: chronic obstructive pulmonary disease; LVEF: left ventricular ejection fraction; NYHA: New York Heart Association; PAD: peripheral artery disease; PCI: percutaneous coronary intervention; SD: standard deviation.
[a]Antidepressants, anticonvulsants, neuroleptics.

improvement over the onset of CR. Thus, the proportion of patients who consumed fruits, vegetables and fish at least once a week was significantly enhanced from 75.2% to 90.5% and 63.1% to 75.9%, respectively ($p < 0.01$ for both). Fewer patients had consumed soft drinks (31.2% vs 18.9%, $p < 0.01$). In addition, patients reported increased PA (1 vs 2.6 days/week; $p < 0.01$). The proportion of smokers decreased from 21.9% to 18.6% ($p = 0.07$). Statistically significant associations between cognitive performance and lifestyle at FU were only detected for the extent of PA (0–1 day/week: 36.4% MCI, 2–4 days/week: 27.2% MCI, 5–7 days/week: 46.3% MCI; $p = 0.01$) and participation in a heart group

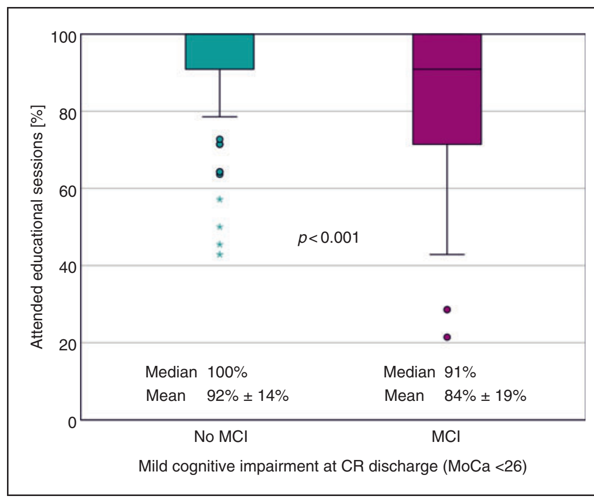

Figure 2. Rate of educational sessions attended based on cognitive performance. CR: cardiac rehabilitation; MCI: mild cognitive impairment; MoCA: Montreal Cognitive Assessment.

Table 2. Functional and psychosocial parameters and disease-related knowledge at baseline and discharge from cardiac rehabilitation (CR) (mean ± standard deviation).

Parameter	CR admission	CR discharge	SES	p-Value
6-Min walking distance (m)	416.5 ± 84.2	499.8 ± 90.6	1.0	<0.001
Exercise capacity (watts)[a]	109.2 ± 36.0	128.7 ± 46.7	0.5	<0.001
HADS: depression (points)	5.4 ± 3.8	3.8 ± 3.4	0.4	<0.001
HADS: anxiety (points)	6.5 ± 4.1	5.1 ± 4.1	0.3	<0.001
MoCA, unadjusted (points)	25.3 ± 3.0	25.7 ± 2.9	0.1	0.010
MoCA, education adjusted[b] (points)	26.1 ± 3.0	26.5 ± 2.9	0.1	0.010
MCI (MoCA<26 points)	142 (36%)	131 (33%)	–	0.300
Knowledge, total (points)	23.3 ± 5.3	26.4 ± 4.5	0.6	<0.001
Knowledge, medical (points)	14.4 ± 3.7	16.5 ± 3.1	0.6	<0.001
Knowledge, lifestyle (points)	8.9 ± 2.2	9.9 ± 1.8	0.5	<0.001

HADS: hospital anxiety and depression scale; MCI: mild cognitive impairment; MoCA: Montreal Cognitive Assessment; SES: standardised effect size.
[a]In bicycle exercise stress test.
[b]One point added for patients with ≤12 years of formal education[17]

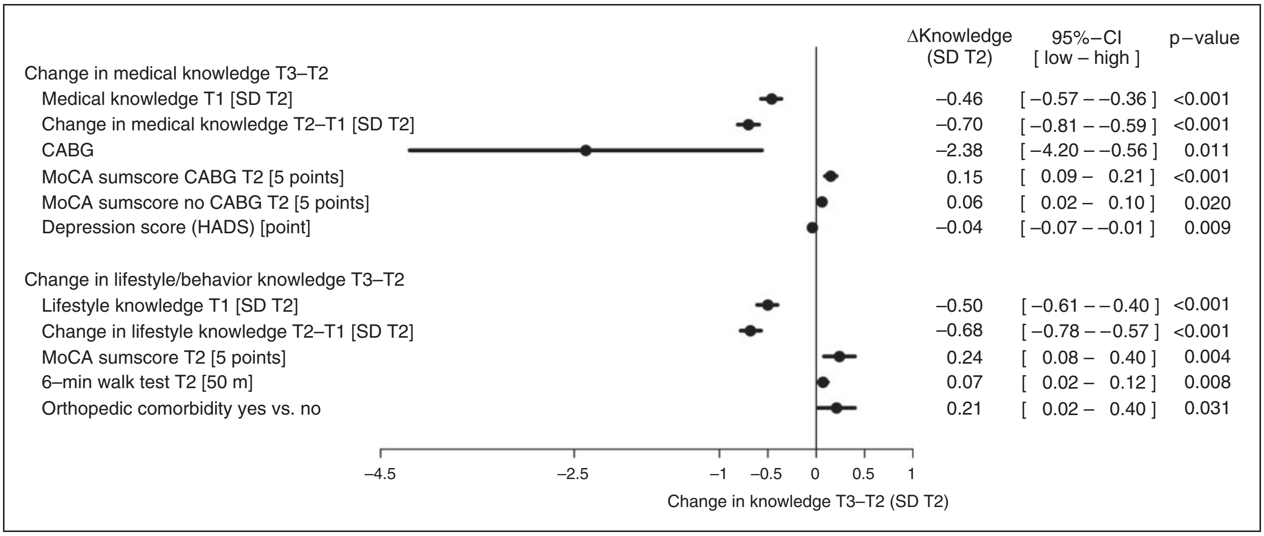

Figure 3. Predictors of sustainability of patient education after cardiac rehabilitation (CR). Changes in disease-related knowledge between discharge from rehabilitation and follow-up six months afterwards are predicted by coronary artery bypass graft (CABG) and cognitive performance at discharge regarding CABG. An enhancement by five points in Montreal Cognitive Assessment (MoCA) in patients after CABG leads to a significant improvement in medical knowledge by +0.15 with the standard deviation of knowledge at discharge from CR as unit. Changes for patients without CABG are smaller (Δ knowledge +0.06 for +5 points in MoCA). The association of cognitive performance and changes in lifestyle knowledge is independent of CABG (Δ knowledge +0.24 for +5 points in MoCA). The presented effect sizes can be interpreted analogously to Cohen's d. Δ knowledge: difference in knowledge quiz (points) between discharge from rehabilitation and follow-up; HADS: Hospital Anxiety and Depression Scale; T1: admission to cardiac rehabilitation; T2: discharge from cardiac rehabilitation; T3: follow-up six months after cardiac rehabilitation; T2–T1: cardiac rehabilitation period; T3–T2: follow-up period.

(participants: 26% MCI vs non-participants: 36.1% MCI; $p = 0.043$).

Predictors of the sustainability of patient education

The changes in patients' disease-related knowledge between discharge from CR and FU were influenced by their cognitive performance in MoCA at discharge from CR. Thus, the difference in overall knowledge (average -0.4 ± 5.9 points) was enhanced by 0.36 points per additional point in the MoCA ($p < 0.01$).

However, in case of medical knowledge, CABG as CR indication moderated this effect. An enhancement by five points in MoCA in patients after CABG resulted in a significant improvement in medical knowledge by +0.15 with the standard deviation of knowledge at discharge from CR as unit ($p < 0.001$). Medical knowledge changes for patients without CABG were smaller (Δ medical knowledge +0.06 for +5 points in MoCA, $p = 0.02$). CABG itself had a large negative independent impact on the changes in medical knowledge during FU-period (Δ medical knowledge –2.38 for CABG vs no CABG, $p = 0.011$). In contrast, the association of cognitive performance and changes in lifestyle knowledge was independent of CABG (Δ knowledge +0.24 for +5 points in MoCA, $p = 0.004$) (Figure 3).

In addition, the sustainability of patient education was affected by the patients' prior knowledge and knowledge enhancement during CR. Furthermore, the level of depression in the HADS was a negative predictor of the preservation of medical knowledge, while an orthopaedic comorbidity as well as a longer six-minute walk distance positively influenced changes in lifestyle knowledge six months after CR (Figure 3).

Discussion

In the present study, patient education during CR resulted in a significant enhancement of the disease-related medical and lifestyle knowledge of younger patients following an acute cardiac event. Six months after CR, the average medical knowledge had slightly but significantly decreased, while lifestyle knowledge remained at a stable level. However, the individual mid-term preservation of knowledge was predicted by patients' prior knowledge, depressive symptoms and, in particular, CABG and the cognitive performance at discharge from CR. In fact, 36% of the examined patients were affected by MCI.

Overall, the current study results attest to a good sustainability of CR patient education. With a closer look, however, there are differences between the average lifestyle knowledge and medical knowledge. The latter was reduced during six months after discharge from CR, in particular in patients after CABG, while no differences between patients with or without CABG regarding the knowledge or knowledge changes and cognitive performance were detectable during CR. Moreover, both CABG and cognitive performance in patients after CABG were independent predictors of sustainability of medical knowledge. Patients after CABG frequently suffer from neuropsychological deficits in the form of executive dysfunction, short-term memory loss and psychomotor slowing.[9] The impairments may result in a lack of consolidation and internalization of declarative semantic contents of patient education (i.e. medical knowledge). However, the causes and underlying mechanism cannot be explained from the current data.

Certainly, patient education for the secondary prevention of cardiovascular diseases is an essential part of CR.[5] Educational interventions have been shown to increase patients' knowledge, as well as behaviour changes regarding physical activity, dietary habits and smoking cessation.[21] However, the latest Cochrane review showed no effect on total mortality.[22] Therefore, educational interventions should only be part of a comprehensive rehabilitation programme. The content, dose and mode of delivery varied substantially between the included interventions, and there is still uncertainty about the optimal approach.[21,22] Effective means of delivery may include a structured approach, individualisation of content, use of multiple teaching strategies and mediums, and repetitive sessions.[23] This also applies to patients with heart failure as well as after bypass surgery,[24–26] which are disproportionately affected by cognitive impairment.[9,27]

These suggestions correspond to the more positive study results for lifestyle knowledge that is not only conveyed via patient education during CR, but is also addressed in other components like physician consultations, nutrition counseling and exercise training. The resulting frequent repetitions of the learning content, cognitive processing and practice were probably a cause of the good preservation of lifestyle knowledge after CR discharge.[28] Accordingly, the patients reported a significantly improved physical activity level and nutritional behaviour at FU. The individual outcome was predicted by the patients' cognitive performance: good cognitive capacity thus contributed significantly to anchoring or further enhancing disease-related knowledge in the medium term.

Bernard et al.[29] were able to prove cognitive decline six months after CR, with primarily functional rather than structural changes. However, several changes in brain structure were detected in elderly CAD patients. In particular, a loss of white and gray matter in the pre- and postcentral cortex, in the right temporal lobe, in the left middle temporal gyrus, in the right precuneus, in the posterior cingulate cortex, and in the left medial frontal lobe including gyrus cinguli were described.[30,31] These structures are associated with internal drive, working memory and other executive functions, attention allocation, reaction time and episodic memory functions, which are imperative for the encoding, consolidation and implementation of educational content.

In the current study, cognitive performance at the time of discharge from CR was crucial. During an intensive three-week CR, the results in the MoCA were enhanced. But, the effects were small and measurement errors in terms of false positive or false negative screening results cannot be excluded.[32] Moreover, there is no evidence for targeted interventions of MCI.[33] However, both physical training and a healthy diet can improve cognitive performance.[34–36] Also, an adequate cardiovascular drug setting seems to have positive effects.[37] Nutrition counseling, exercise training and risk factor management are core components of CR.[5] Consequently, we can assume positive effects of CR also on the cognitive performance of CAD patients.[38–40] This applies particularly to longer-term rehabilitation programmes, such as those offered in the UK or USA.

Nonetheless, a high prevalence of cognitive impairment in CR patients must be expected in these countries during and at the end of CR as well. Therefore, adequate education strategies for CR especially with regard to therapy adherence are essential. In addition, the content should be critically scrutinised and prioritised in terms of practical relevance and action-orientation, avoiding excessive demands on the patients. The diminished participation of MCI patients in the educational sessions in this study could indicate an overload on the patient. Generally, patient education should not focus only on providing information. Modern self-management education comprises an interactive, patient-oriented process targeting knowledge, attitudes, motivational factors, skills and behaviours. Therefore, patient education should be an integral part of all therapy components in order to foster learning and competencies through references, repetitions and practice.[28]

Such a concept would benefit all patients, both with and without cognitive impairment. On the other hand, special education offers to impaired patients are not recommended. Both the personal and organisational effort would be disproportionately high. Furthermore, the required cognition screening and separate treatment of impaired patients could lead to a stigma and a promotion of negatively associated depressive symptoms.

Limitations

In this investigation, cognitive performance was detected using a global screening instrument. Statements about impairments to individual functions are not possible. Cognitive performance at six months after CR was not determined. No information is available for progression or recovery, despite cognitive decline after CABG being frequently described as subtle and transient with varying duration of impairment.[9,41–43] Possible influences on medium term changes in knowledge were not examined and should be investigated in further studies.

Moreover, there is a selection bias: FU responders had a healthier lifestyle (nutrition, smoking) and better medical knowledge at the start and end of CR than non-responders ($n = 96$). As a result, more homogeneous knowledge values and an overestimation of the predictors are possible. However, both responders and non-responders showed no differences in cognitive performance.

Further, the knowledge quiz at FU was administered without supervision in the patients' homes. Small manipulations can, therefore, not be excluded. However, the statistics do not indicate that this happened.

Finally, some organizational issues regarding the patient education programme in this observational study were different in the participating centres (e.g. session frequency depended on number of participants).

Conclusion

Patient education in CR led to enhanced disease-related knowledge, while medical knowledge was reduced in the medium term. This effect is essentially influenced by prior knowledge, CABG and cognitive performance in patients after CABG. On the other hand, cognitive performance regardless of CABG predicted the maintenance of lifestyle knowledge. Overall, about one-third of the investigated patients with CAD following an acute cardiac event in CR were affected by cognitive impairments. Therefore, patient education concepts in CR should be reconsidered, in particular, with respect to individualisation and priorisation of content and teaching strategies, and adjusted as needed.

Author contribution

AS, MDH, MS, KW and HV conceived and designed the study. AS, MDH, KM and HV contributed to the neuropsychological and educational aspects of the investigation. MS and HV were responsible for the acquisition of patients and data. AS, MDH, KM, KW, RR and HV contributed to the analysis and interpretation of the work. AS drafted the manuscript. All authors critically read and revised the manuscript and approved the final version.

Acknowledgements

The authors gratefully acknowledge all participating patients and the staff of the cooperating CR centres. They especially thank Kirsten Stolze, Klinik am See, Rüdersdorf, and Katarina Külbel, Brandenburg Klinik, Bernau, who ensured patient enrolment and management.

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 German Federal Pension Insurance (grant no. 0421/00-40-64-50-39).

References

1. Piepoli MF, Hoes AW, Agewall S, et al. 2016 European guidelines on cardiovascular disease prevention in clinical practice: The Sixth Joint Task Force of the European Society of Cardiology and Other Societies on Cardiovascular Disease Prevention in Clinical Practice (constituted by representatives of 10 societies and by invited experts) Developed with the special contribution of the European Association for Cardiovascular Prevention & Rehabilitation (EACPR). *Atherosclerosis* 2016; 252: 207–274.
2. Rauch B, Davos CH, Doherty P, et al. The prognostic effect of cardiac rehabilitation in the era of acute revascularisation and statin therapy: A systematic review and meta-analysis of randomized and non-randomized studies – The Cardiac Rehabilitation Outcome Study (CROS). *Eur J Prev Cardiol* 2016; 23: 1914–1939.
3. Bjarnason-Wehrens B, McGee H, Zwisler A-D, et al. Cardiac rehabilitation in Europe: Results from the European Cardiac Rehabilitation Inventory Survey. *Eur J Cardiovasc Prev Rehabil* 2010; 17: 410–418.
4. Bjarnason-Wehrens B, Held K, Hoberg E, et al. Deutsche Leitlinie zur Rehabilitation von Patienten mit Herz-Kreislauferkrankungen (DLL-KardReha). *Clin Res Cardiol Suppl* 2007; 2: 1–54.
5. Piepoli MF, Corrà 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.
6. Meng K, Seekatz B, Haug G, et al. Evaluation of a standardized patient education program for inpatient cardiac rehabilitation: Impact on illness knowledge and self-management behaviors up to 1 year. *Health Educ Res* 2014; 29: 235–246.
7. Cannon JA, Moffitt P, Perez-Moreno AC, et al. Cognitive impairment and heart failure: Systematic review and meta-analysis. *J Card Fail* 2017; 23: 464–475.

8. Deckers K, Schievink SHJ, Rodriquez MMF, et al. Coronary heart disease and risk for cognitive impairment or dementia: Systematic review and meta-analysis. *PLoS One* 2017; 12: e0184244.
9. Raja PV, Blumenthal JA and Doraiswamy PM. Cognitive deficits following coronary artery bypass grafting: Prevalence, prognosis, and therapeutic strategies. *CNS Spectr* 2004; 9: 763–772.
10. Singh-Manoux A, Kivimaki M, Glymour MM, et al. Timing of onset of cognitive decline: Results from Whitehall II prospective cohort study. *BMJ* 2012; 344: d7622.
11. Knopman D, Boland LL, Mosley T, et al. Cardiovascular risk factors and cognitive decline in middle-aged adults. *Neurology* 2001; 56: 42–48.
12. Almeida OP, Garrido GJ, Beer C, et al. Cognitive and brain changes associated with ischaemic heart disease and heart failure. *Eur Heart J* 2012; 33: 1769–1776.
13. Winblad B, Palmer K, Kivipelto M, et al. Mild cognitive impairment–beyond controversies, towards a consensus: Report of the International Working Group on Mild Cognitive Impairment. *J Intern Med* 2004; 256: 240–246.
14. Rauch B, Riemer T, Schwaab B, et al. Short-term comprehensive cardiac rehabilitation after AMI is associated with reduced 1-year mortality: Results from the OMEGA study. *Eur J Prev Cardiol* 2014; 21: 1060–1069.
15. Karoff M, Held K and Bjarnason-Wehrens B. Cardiac rehabilitation in Germany. *Eur J Cardiovasc Prev Rehabil* 2007; 14: 18–27.
16. Seekatz B, Haug G, Mosler G, et al. Entwicklung und kurzfristige Effektivität eines standardisierten Schulungsprogramms für die Rehabilitation bei koronarer Herzkrankheit. *Rehabilitation (Stuttg)* 2013; 52: 344–351.
17. Nasreddine ZS, Phillips NA, Bédirian V, et al. The Montreal Cognitive Assessment, MoCA: A brief screening tool for mild cognitive impairment. *J Am Geriatr Soc* 2005; 53: 695–699.
18. Costa AS, Fimm B, Friesen P, et al. Alternate-form reliability of the Montreal Cognitive Assessment screening test in a clinical setting. *Dement Geriatr Cogn Disord* 2012; 33: 379–384.
19. Costa AS, Reich A, Fimm B, et al. Evidence of the sensitivity of the MoCA alternate forms in monitoring cognitive change in early Alzheimer's disease. *Dement Geriatr Cogn Disord* 2014; 37: 95–103.
20. Kazis LE, Anderson JJ and Meenan RF. Effect sizes for interpreting changes in health status. *Medical Care* 1989; 27: 178–189.
21. Ghisi GLdM, Abdallah F, Grace SL, et al. A systematic review of patient education in cardiac patients: Do they increase knowledge and promote health behavior change? *Patient Educ Couns* 2014; 95: 160–174.
22. Anderson L, Brown JP, Clark AM, et al. Patient education in the management of coronary heart disease. *Cochrane Database Syst Rev* 2017; 6: CD008895.
23. Friedman AJ, Cosby R, Boyko S, et al. Effective teaching strategies and methods of delivery for patient education: A systematic review and practice guideline recommendations. *J Cancer Educ* 2011; 26: 12–21.
24. Fredericks S, Beanlands H, Spalding K, et al. Effects of the characteristics of teaching on the outcomes of heart failure patient education interventions: A systematic review. *Eur J Cardiovasc Nurs* 2010; 9: 30–37.
25. Fredericks S, Ibrahim S and Puri R. Coronary artery bypass graft surgery patient education: A systematic review. *Prog Cardiovasc Nurs* 2009; 24: 162–168.
26. Strömberg A. The crucial role of patient education in heart failure. *Eur J Heart Fail* 2005; 7: 363–369.
27. Doehner W, Ural D, Haeusler KG, et al. Heart and brain interaction in patients with heart failure: Overview and proposal for a taxonomy. A position paper from the Study Group on Heart and Brain Interaction of the Heart Failure Association. *Eur J Heart Fail* 2018; 20: 199–215.
28. Bitzer EM and Spörhase U. Gesundheitskompetenz in der medizinischen Rehabilitation und die Bedeutung für die Patientenschulung. *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz* 2015; 58: 983–988.
29. Bernard C, Catheline G, Dilharreguy B, et al. Cerebral changes and cognitive impairment after an ischemic heart disease: A multimodal MRI study. *Brain Imaging Behav* 2016; 10: 893–900.
30. Almeida OP, Garrido GJ, Beer C, et al. Coronary heart disease is associated with regional grey matter volume loss: Implications for cognitive function and behaviour. *Intern Med J* 2008; 38: 599–606.
31. Santiago C, Herrmann N, Swardfager W, et al. White matter microstructural integrity is associated with executive function and processing speed in older adults with coronary artery disease. *Am J Geriatr Psychiatry* 2015; 23: 754–763.
32. Salzwedel A, Heidler M-D, Haubold K, et al. Prevalence of mild cognitive impairment in employable patients after acute coronary event in cardiac rehabilitation. *Vasc Health Risk Manag* 2017; 13: 55–60.
33. Deutsche Gesellschaft für Psychiatrie und Psychotherapie, Psychosomatik und Nervenheilkunde and Deutsche Gesellschaft für Neurologie. S3-Leitlinie 'Demenzen'. Berlin, Heidelberg: Springer Berlin Heidelberg, 2017: 104.
34. Tanne D, Freimark D, Poreh A, et al. Cognitive functions in severe congestive heart failure before and after an exercise training program. *Int J Cardiol* 2005; 103: 145–149.
35. Feart C, Samieri C and Barberger-Gateau P. Mediterranean diet and cognitive health: An update of available knowledge. *Curr Opin Clin Nutr Metab Care* 2015; 18: 51–62.
36. Scarmeas N, Luchsinger JA, Schupf N, et al. Physical activity, diet, and risk of Alzheimer disease. *JAMA* 2009; 302: 627–637.
37. Rattinger GB, Dutcher SK, Chhabra PT, et al. The effect of dementia on medication use and adherence among Medicare beneficiaries with chronic heart failure. *Am J Geriatr Pharmacother* 2012; 10: 69–80.
38. Gunstad J, Macgregor KL, Paul RH, et al. Cardiac rehabilitation improves cognitive performance in older

adults with cardiovascular disease. *J Cardiopulm Rehabil* 2005; 25: 173–176.
39. Stanek KM, Gunstad J, Spitznagel MB, et al. Improvements in cognitive function following cardiac rehabilitation for older adults with cardiovascular disease. *Int J Neurosci* 2011; 121: 86–93.
40. Alosco ML, Spitznagel MB, Cohen R, et al. Cardiac rehabilitation is associated with lasting improvements in cognitive function in older adults with heart failure. *Acta Cardiol* 2014; 69: 407–414.
41. Newman MF, Kirchner JL, Phillips-Bute B, et al. Longitudinal assessment of neurocognitive function after coronary-artery bypass surgery. *N Engl J Med* 2001; 344: 395–402.
42. Selnes OA, Grega MA, Borowicz LM, et al. Cognitive changes with coronary artery disease: A prospective study of coronary artery bypass graft patients and nonsurgical controls. *Ann Thorac Surg* 2003; 75: 1377–1384; discussion 1384-1386.
43. Selnes OA and McKhann GM. Neurocognitive complications after coronary artery bypass surgery. *Ann Neurol* 2005; 57: 615–621.