

Functional capacity and patient-reported outcome measures after cardiac rehabilitation: a prospective study with 6-month follow-up

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Summary

AIMS: This exploratory study aimed to assess the changes in functional capacity and patient-reported outcome measures (PROMs) experienced by outpatients undergoing cardiac rehabilitation; and factors associated with health-related quality of life.

METHODS: We prospectively included all consecutive patients diagnosed with various cardiac conditions who had undergone a 10-week multidisciplinary cardiac rehabilitation programme from October 2020 to October 2022. The primary outcomes were functional capacity, including the 6-minute walk test, maximal short-term exercise capacity, estimated metabolic equivalent of task (eMET) and maximal quadriceps isometric strength at entry and discharge; and PROMs including the Hospital Anxiety and Depression Scale (HADS), quality of life (HeartQoL), and level of work, sport and leisure physical activity (Baecke) at entry, discharge and at 6 months. Secondly, we assessed factors associated with heart-related quality of life over the 6-month period using multi-level mixed-effects generalised linear models adjusted for age, sex and time point.

RESULTS: Among the 273 included patients, 81% were men and the median age was 63 years (range: 57–69). From programme entry to discharge, median values significantly increased for the 6-minute walk test (+60 m, 95% CI: 50–65), maximal short-term exercise capacity (+50 W, 95% CI: 50–50), eMET (+0.9, 95% CI: 0.7–1.1), maximal left quadriceps isometric strength (+3 Nm, 95% CI: 2–4) and maximal right quadriceps isometric strength (+4 Nm, 95% CI: 2.4–4.7). The median scores of depression, anxiety, physical and emotional heart-related quality of life and leisure activity were significantly improved from entry to the 6-month follow-up. The physical domain of quality of life was associated with the 6-minute walk test (coefficient: 1.001, 95% CI: 1.00–1.001) and anxiety score (coefficient: 0.97, 95% CI: 0.96–0.99) while the emotional domain was associated with level of depression (coefficient:

0.95, 95% CI: 0.94–0.97) and anxiety (coefficient: 0.98, 95% CI: 0.97–0.99).

CONCLUSIONS: Our study showed that functional capacity significantly improved at discharge from the cardiac rehabilitation programme, as did the symptoms of anxiety and depression, quality of life and leisure-time physical activity at 6 months. The 6-minute walk test and symptoms of depression or anxiety were found to be significantly associated with quality of life. A cardiac rehabilitation programme could be proposed to eligible cardiac patients to improve their outcomes.

Introduction

Cardiovascular diseases are the most common cause of death and the third cause of hospitalisation in Switzerland [1]. A meta-analysis of 63 randomised controlled trials suggested that cardiac rehabilitation could significantly reduce cardiovascular mortality (relative risk: 0.74;95% confidence interval [CI]: 0.64–0.86) and hospital admissions (relative risk: 0.82;95% CI: 0.70–0.96) and improve quality of life (QoL) [2].

Functional capacity reflects an individual's tolerance to perform activities under aerobic metabolism like walking, exercising or maintaining a body position [3]. It can be assessed by various measurements including the 6-minute walk test (6MWT), estimated metabolic equivalent of task (eMET), maximal short-term exercise capacity and maximal quadriceps isometric strength. Patients with cardiac diseases often demonstrate impaired functional capacity that could lead to a reduction in social or daily activities [4]. Improvements in functional capacity indicators, such as the 6-minute walk test and eMET, have been demonstrated in patients undergoing exercise-based cardiac rehabilitation programmes [5, 6], but few studies have reported the latter two tests (maximal short-term exercise capacity and quadriceps isometric strength) after completion of a cardiac rehabilitation programme. A change in these para-

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meters after a cardiac rehabilitation programme should be evaluated.

In addition to objective measurements, patient-reported outcome measures (PROMs) including quality of life, depression, anxiety and level of physical activity are outcomes of interest because they are associated with mortality rate, hospitalisation and healthcare expenditures in patients with cardiac diseases [7–9]. According to a meta-analysis of 12 randomised controlled trials, the mean values for depression and anxiety significantly decreased (–0.34 points) in individuals with cardiovascular diseases after completing cardiac rehabilitation [10]. Physical activity also improved on discharge from a cardiac rehabilitation programme [11]. However, it remains unclear whether these improvements are maintained over time.

Factors associated with quality of life in patients who underwent cardiac rehabilitation were age, sex, number of comorbidities, psychological distress and physical activity [12–14]. Previous studies have also showed a significant association of functional capacity indicators, including eMET [15] and peak oxygen uptake [16], with quality of life. However, these studies were based on cross-sectional designs [15, 16], and did not assess changes in variables over time. A follow-up study could assess the changes in these parameters across different time points and provide a comprehensive predictive model.

According to a 2019 report by the European Association of Preventive Cardiology, cardiac rehabilitation was available in 90% (40/44) of European countries, albeit with regional variations [17]. On average, cardiac rehabilitation programmes had a multidisciplinary team of 6.5 staff members and offered 8.5 of 10 core components over a duration of 24.8 hours. Participation in either inpatient or outpatient cardiac rehabilitation yielded comparable results in terms of cardiac mortality and morbidity, functional capacity and physical activity [18]. In Switzerland, the cardiac rehabilitation programme follows the guidelines proposed by the Swiss Working Group for Cardiovascular Prevention, Rehabilitation and Sports Cardiology (SCPRS) [19]. A 2023 Swiss report from 82 registered centres of 133,060 participants showed that cardiac rehabilitation programmes could improve functional capacity, quality of life and smoking cessation rates [20]. However, there are some shortcomings concerning this registry database. Most data represent means or medians of each centre, rather than individual data. Additionally, the use of various questionnaires in registry databases could lead to data heterogeneity. Analysing individual data from medical records might overcome these shortcomings.

To this end, we aimed to assess changes in functional capacity (6-minute walk test, eMET, maximal short-term exercise capacity, quadriceps isometric strength) upon discharge and in PROMs (depression, anxiety, quality of life, level of physical activity) at 6-month follow-up among outpatients who had completed cardiac rehabilitation in a prospective study. Additionally, we evaluated factors associated with changes in quality of life using a multi-level mixed-effects generalised linear model adjusted for age, sex and time points.

Materials and methods

Study design and population

This was a prospective study of outpatients who had completed a cardiac rehabilitation programme in a tertiary care rehabilitation clinic from October 2020 to October 2022. People with various cardiac diseases after acute hospitalisation at the Centre Hospitalier du Valais Romand (CHVR) were screened for eligibility for the cardiac rehabilitation programme at the nearby tertiary care rehabilitation centre.

Inclusion criteria were: age 18 to 75 years; heart diseases including acute coronary syndromes with or without percutaneous transluminal coronary angioplasty, heart surgery (mitral valve, aortic valve, intervention on large vessels), chronic coronary artery disease, primary prevention of cardiovascular disease and cardiac insufficiency. All patients were able to understand and sign an informed consent form.

Exclusion criteria were: under legal custody, unstable or life-threatening non-cardiovascular conditions including active infection, uncontrolled diabetes or end-stage cancer, unstable angina, uncontrolled malignant ventricular arrhythmias, overt cardiac insufficiency not controlled by medication, unoperated severe aortic valve stenosis, lung disease with severe hypoxia, ancillary conditions that are adversely affected by physical activity or that prohibit physical activity, substantial locomotor disability or physical dependence and insufficient potential for independence and reintegration and finally severe psychopathy or drug addiction with uncontrolled overt addiction. Moreover, we also excluded patients who had not performed functional tests at entry or discharge.

Measured data

We collected baseline data (age, sex, diagnoses, smoking status at entry) at admission. Our primary outcomes were functional capacity including the 6-minute walk test [21], maximal short-term exercise capacity [22], eMET [23] and maximal quadriceps isometric strength [24] at entry and discharge; and PROMs including the Hospital Anxiety and Depression Scale (HADS), heart-related quality of life (HeartQuL), Baecke questionnaire; at entry, discharge and 6 months later.

Functional capacity measurement

The eMET was calculated by using the exercise stress test on the treadmill (h/p cosmos, Nussdorf – Traunstein, Germany) according to the Bruce protocol [23]. The protocol comprises 7 exercise stages of three minutes each. At each stage, the speed and gradient of the treadmill are increased to increase work output. For example, stage 1 of the Bruce protocol is performed at 2.7 km per hour (kph) with a 10% incline, stage 2 at 4 kph and 12%, stage 3 at 5.5 kph and 14%, etc. Heart rate and respiratory rate are constantly assessed; blood pressure and electrocardiogram (ECG) are taken at rest, after each stage and during recovery for at least 5 minutes or until return to baseline. The test stops if the individual shows signs or symptoms of impaired blood flow to the heart, irregular heart rhythm, fatigue, shortness of breath, wheezing, leg cramps or chest discomfort. The following Bruce protocol-specific equation accounts for

handrail use: $eMETs = (2.587 \times TT + 6.004)/3.5$, where TT is exercise time in minutes [3].

The 6-minute walk test [21] is a reliable and validated submaximal exercise test for patients with cardiac disease. Participants were instructed to walk as fast and as far as they could do for 6 minutes on a 120-metre walking track. The distance walked was recorded in metres.

The maximal short-term exercise capacity [25] is determined using an ergometer steep ramp test (SRT) (Ergoline GmbH, Ergoline, Germany). After a warm-up of 2 minutes of unloaded cycling, the resistance was progressively increased (25 W/10 s). Patients were instructed to cycle until exhaustion with a pedal frequency of 60–80 rotations per minute (rpm). The test was stopped when the pedal frequency dropped under 60 rpm. The steep ramp test is a practicable, reliable and validated test for the assessment of the training dose [25].

The maximal quadriceps isometric strength [24] was measured with an isometric measurement device (Easytorque, Fa. Tonus, Zemmer, Germany) with the individual in a sitting position. The knee angle was set to 80° to measure knee flexion and 90° for knee extension. The thighs were fixed with pads and the calves were pressed isometrically against the pads, thus against the force transducers. The individual had to build up strength for 5 s and hold it for 5 s more. Both sides were tested alternately. Three isometric measurements were taken for each side, and the maximum value achieved was retained. The correlation between measurements with a fixed handheld dynamometer and the isokinetic dynamometer method were statistically significant [26].

Self-reported questionnaires

The HADS [27] was used to assess the level of depression and anxiety. The HADS includes 7 items related to symptoms of anxiety and 7 to symptoms of depression. Scores range from 0 to 21, with higher scores indicating greater symptom severity. A score ≥ 8 indicates possible or probable clinically relevant anxiety and/or depression [28].

The heart-related quality of life [29, 30] questionnaire is a 14-item self-assessment questionnaire used to measure health-related quality of life. The scale includes a 10-item physical subscale (Cronbach's alpha: 0.91) and a 4-item emotional subscale (Cronbach's alpha: 0.87) [31]. Items are rated on a 4-point Likert scale (range 0–3), with higher scores indicating higher quality of life. Scores for each subscale are calculated as the mean of items. The heart-related quality of life questionnaire has been validated in the EuroAspire IV Health Survey in 7449 stable coronary patients [31].

The Baecke questionnaire [32] contains 16 questions distributed across 3 domains: physical activity at work (items 1–8), physical activity in sports (items 9–12) and leisure-time physical activity excluding sports (items 13–16). Each item is scored on a Likert scale ranging from 1 to 5 and a specific formula provides a score between 1 and 5 for each assessed domain.

The work domain score is calculated by summing the responses in the domain (for item 2, the value used is the response subtracted from 6) and then dividing by 8. The sports domain score is computed by summing the values

and dividing by 4. To calculate the leisure domain score, the summed values (for item 13, the value used is the response subtracted from 6) are divided by 4. For each domain, the final score ranges from 1 to 5, with a higher score indicating a higher level of physical activity [32].

Cardiac rehabilitation programme

The cardiac rehabilitation programme is a multidisciplinary approach developed according to the SCPRS guidelines [19]. The cardiac rehabilitation team consisted of different healthcare professionals (cardiologists, angiologists, physiotherapists, sports instructors, nurses, psychiatrists, psychologists, dieticians, biologists). The programme lasts 10 weeks, with 3 half-days of treatment per week. It consists of exercise (aerobic and resistance training), psychiatric intervention (stress management) and therapeutic education (cardiac physiology and pathology, medications, cardiovascular risk factors, diet). The exercise training includes nearly 70 hours of gym and water exercises, outdoor walking and relaxation sessions. There are five groups of different intensity levels that are adapted to the specific needs of the person, their state of health and evolution. The training is carried out with a maximum of 13 people; each session lasts 40 minutes. There is one excursion of 1.5 hour per week. Therapeutic education is provided in an interactive way to enable people to adopt habits that are sustainable and favourable to health.

Statistical analysis

This is an exploratory study, and we did not calculate the sample size beforehand. Categorical variables (sex, cardiac diagnoses, intervention, smoking status at entry) are presented with counts (%). Normal distribution was checked using the Shapiro-Wilk tests. Continuous variables including age, functional capacity tests and PROMs were not normally distributed and are presented as median and interquartile range (IQR, the 25th to 75th percentile).

We used Wilcoxon signed-rank tests to compare functional capacity (6-minute walk test, eMET, maximal short-term exercise capacity, quadriceps isometric strength) between discharge and entry level; and Kruskal-Wallis tests to compare the PROMs between three time points (entry, discharge, 6 months), followed by Dunn's post-hoc tests with Bonferroni corrections for multiple comparisons.

Missing data

The frequencies of missing data were as follow: functional tests (quadriceps isometric strength, eMET: 18%); HADS: 22%, heart-related quality of life: 29%, Baecke: 30%. We used complete case analysis to address missing data.

We used multilevel mixed-effects generalised linear models to assess factors associated with physical and emotional domains of heart-related quality of life. The two models included age, sex, time point, smoking status at entry, functional capacity, level of depression and anxiety, physical activity as fixed effects and subjects as random intercept. The significance level for all tests was 0.05. This model allows regression analyses on dependent variables that are non-normally distributed for longitudinal data [33]. We applied a logarithmic link (to transform outcomes into normally distributed variables) and a gaussian function in the

models, using the *meglm* command in STATA 18.0 for Windows (Stata Corp., College Station, TX, USA). For interpretation, the β coefficient was backtransformed and presented as $\exp\beta$. The coefficients in the model estimate the average change of response variable for every 1-unit increase in a covariate.

Ethical considerations

All participants provided written consent. The study protocol was approved by the local ethics committee (Commission cantonale d'éthique de la recherche sur l'être humain CER-VD Lausanne, Project-ID 2020-02155). The investigation conforms to the principles outlined in the Declaration of Helsinki [34].

Results

Baseline characteristics

Among 494 participants screened for eligibility for the cardiac rehabilitation programme during the study period, 7 patients refused to participate and 144 did not give consent for the study. Another 70 patients who did not perform functional tests at entry or discharge were also excluded.

A total of 273 participants were included in the final analysis. Figure 1 presents the flowchart of the study. The median time from acute hospitalisation to cardiac rehabilitation participation was 1.4 months (IQR: 1.1–2.0). The median age was 63 years (range: 57–69), 81% of participants were men and 32% were smokers. About two-thirds of the participants (76%) had a diagnosis of acute coronary syndrome with or without percutaneous coronary intervention (ACS $\pm$ PCI) (table 1).

Functional capacity

At discharge after the cardiac rehabilitation programme, median changes for the 6-minute walk test were significant (+60 m, 95% confidence interval [CI]: 50–65; $p < 0.001$); similarly for the maximal short-term exercise capacity (+50 W, 95% CI: 50–50; $p < 0.001$), eMET (+0.9, 95% CI: 0.7–1.1; $p < 0.001$), maximal left quadriceps isometric strength (+3 Nm, 95% CI: 2–4; $p < 0.001$) and maximal right quadriceps isometric strength (+4 Nm, 95% CI: 2.4–4.7; $p < 0.001$) (table 2). Figure 2 shows the changes in functional capacity from entry to discharge.

Figure 1: Study flowchart.

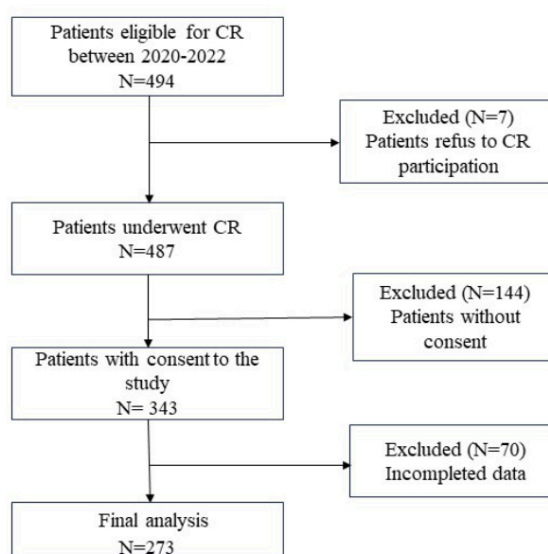


Table 1:
Baseline characteristics of participants (n = 273).

Variables		Total (n = 273)
Age in years, median (IQR)		63 (57–69)
Sex, n (%)	Male	222 (81%)
	Female	51 (19%)
Cardiac intervention, n (%)	Acute coronary syndrome $\pm$ PCI	207 (76%)
	Heart valve surgery	31 (11%)
	Heart insufficiency	13 (5%)
	Intervention on large vessels	5 (2%)
	Other	17 (6%)
Smoking at entry, n (%)	Yes	84 (32%)

IQR: interquartile range; PCI: percutaneous coronary intervention.

Patient-reported outcome measures (PROMs)

The median scores of depression significantly decreased from entry to discharge (from 5 to 4 points, $p < 0.001$) and from entry to 6 months (5 to 4.5 points, $p < 0.001$). The median anxiety scores significantly decreased from entry to discharge (5 to 4 points, $p < 0.001$) and from entry to 6 months (5 to 4 points, $p < 0.001$) (table 3). Differences in median scores of anxiety and depression were not statistically significant between discharge and 6 months.

The median score for the physical domain of quality of life significantly increased from entry to discharge (19 to 24 points, $p < 0.001$) and from entry to 6 months (19 to 25 points, $p < 0.001$). The median score of the emotional domain of quality of life significantly increased from entry to discharge (9 to 11 points, $p < 0.001$) and from entry to 6 months (9 to 11 points, $p < 0.001$) (table 3). Differences in median scores of the physical or emotional domain of

quality of life were not statistically significant between discharge and 6 months.

Median scores for work and sports subscales (Baecke) scores did not significantly differ over the 6-month follow-up. The median score for leisure-time physical activity remained unchanged from entry to discharge (3 points) but slightly improved at 6 months (3.0 to 3.2 points, $p = 0.007$) as compared to the baseline level (table 3). Differences in median scores of leisure-time physical activity were not statistically significant between discharge and 6 months.

Figure 3 shows the changes in PROMs at three time points: entry, discharge and 6 months.

The changes in functional capacity and PROMs according to cardiac condition (ACS ± PCI versus others) are presented in appendix tables S1 and S2.

Table 2:
Functional capacity at entry and discharge from the cardiac rehabilitation programme.

	n	Entry, median (IQR)	Discharge, median (IQR)	Change, median (95% CI)	p-value*
6-minute walk test (m)	273	560 (500–610)	630 (570–680)	60 (50–65)	<0.001
Maximal short-term exercise capacity (W)	273	225 (150–275)	275 (200–325)	50 (50–50)	<0.001
Maximal left quadriceps isometric strength (Nm)	223	43 (34–53)	48 (38–57)	3 (2–4)	<0.001
Maximal right quadriceps isometric strength (Nm)	223	44 (34–55.5)	50 (40–58)	4 (2.4–4.7)	<0.001
eMET	223	8.4 (6.5–10.6)	10.1 (7.2–11.4)	0.9 (0.7–1.1)	<0.001

CI: confidence interval; eMET: estimated metabolic equivalent of task; IQR: interquartile range.
* Wilcoxon signed-rank tests.

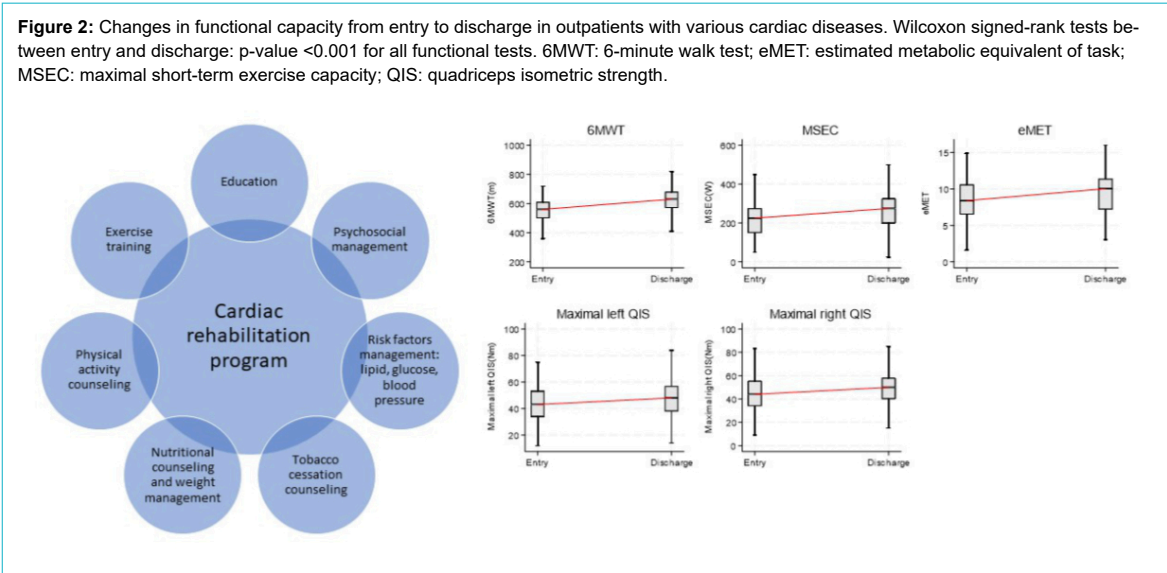


Table 3:
Patient-reported outcome measures of depression and anxiety, quality of life and physical activity during the 6-month follow-up.

Patient-reported outcome measure (PROM)		n	Entry	Discharge	6-month time point	Kruskal-Wallis tests for 3 groups
			Median (IQR)	Median (IQR)	Median (IQR)	
HADS	Depression	212	5 (3–9)	4 (2–7)	4.5 (3–7)	<0.001
	Anxiety	212	5 (4–7)	4 (2–6)	4 (3–7)	<0.001
Heart-related quality of life	Physical	195	19 (15–24)	24 (20–27)	25 (19–27)	<0.001
	Emotional	195	9 (7–11)	11 (9–12)	11 (9–12)	<0.001
Baecke	Work	192	2.4 (1–3.4)	2.6 (1.5–3.4)	2.1 (1–3.4)	0.05
	Sport	192	2.5 (2–3.3)	2.8 (2–3.3)	2.8 (2–3.3)	0.14
	Leisure	192	3.0 (2.3–3.3)	3.0 (2.7–3.7)	3.2 (2.7–3.7)	0.007

HADS: Hospital Anxiety and Depression Scale; IQR: interquartile range.

Factors associated with heart-related quality of life

Linear mixed models showed the physical domain of quality of life was associated with 6-minute walk test (coefficient: 1.001, 95% CI: 1.00–1.001) and scores of anxiety (coefficient: 0.97, 95% CI: 0.96–0.99) (table 4). The emotional domain was associated with the depression scores (coefficient: 0.95, 95% CI: 0.94–0.97) and anxiety (coefficient: 0.98, 95% CI: 0.97–0.99) after being adjusted for age, sex and time point (table 4).

Discussion

Our cardiac patients exhibited a significant improvement in functional capacity (6-minute walk test, estimated meta-

bolic equivalent of task [eMET], maximal short-term exercise capacity, maximal quadriceps isometric strength) upon discharge after a 10-week cardiac rehabilitation programme, alongside improvements in quality of life, symptoms of depression and anxiety and the level of leisure-time physical activity from entry to 6-month follow-up. These results align with existing evidence, underscoring the benefits of a cardiac rehabilitation programme regarding the outcomes of interest [35, 36]. Moreover, the 6-minute walk test and the levels of depression or anxiety have been found to associate significantly with quality of life.

Our results showed a gain of 60 m in the median scores of 6-minute walk test, comparable to the results of a systematic review of 15 studies [5]. The Minimal Clinically Im-

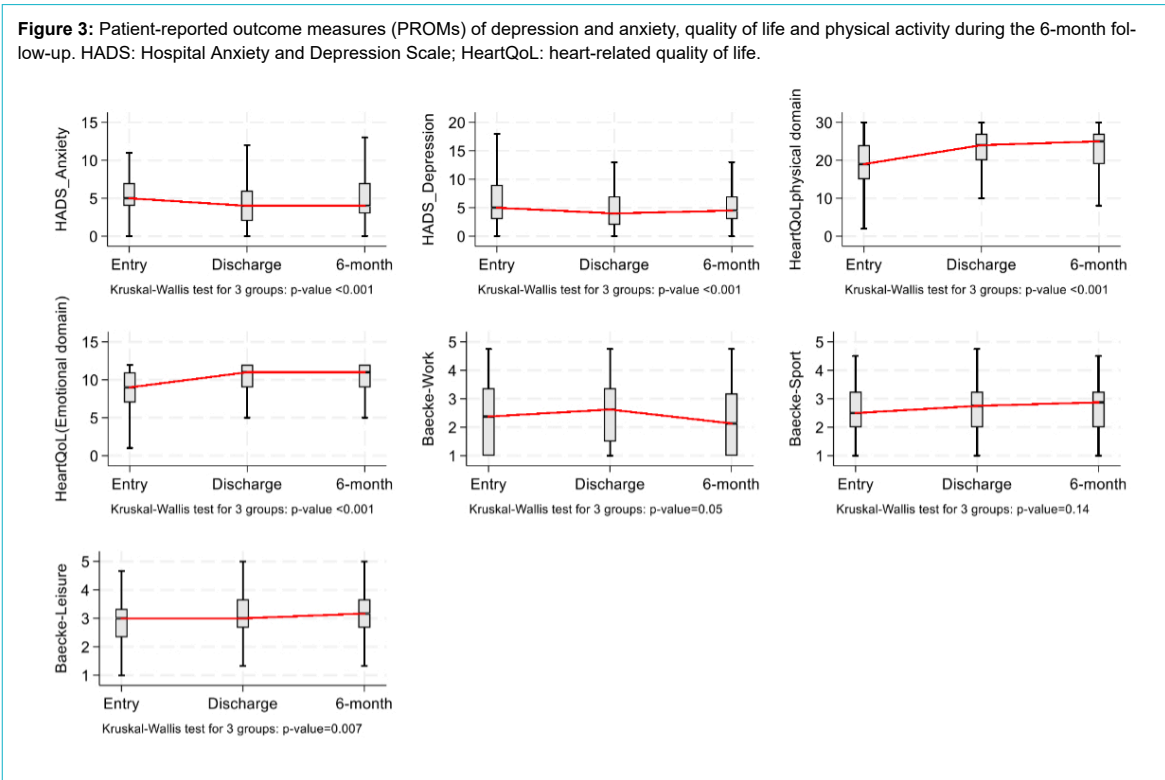


Table 4: Results of the generalised mixed models regarding the association between different factors with heart-related quality of life (HeartQoL) dimensions. Case-complete analysis was applied for missing data. The coefficients in the model estimate the average change of the response variable for every 1-unit increase in a covariate.

	Physical domain (n = 192)				Emotional domain (n = 192)			
	expβ	p-value	95% CI		expβ	p-value	95% CI	
Age	1.00	0.30	1.00	1.01	1.00	0.52	1.00	1.00
Sex	0.97	0.67	0.86	1.10	1.06	0.23	0.97	1.16
Smoking status	1.06	0.20	0.97	1.15	0.99	0.67	0.93	1.05
6-minute walk test	1.001	0.02	1.00	1.001	1.00	0.29	1.00	1.00
Maximal short-term exercise capacity	1.00	0.59	1.00	1.00	1.00	0.39	1.00	1.00
eMETs	1.01	0.13	1.00	1.01	1.00	0.68	0.99	1.01
Quadriceps isometric strength left	1.00	0.63	1.00	1.01	1.00	0.94	1.00	1.00
Quadriceps isometric strength right	1.00	0.94	1.00	1.00	1.00	0.45	1.00	1.00
Depression (HADS) (range: 0–21)	1.00	0.50	0.98	1.01	0.95	<0.001	0.94	0.97
Anxiety (HADS) (range: 0–21)	0.97	0.004	0.96	0.99	0.98	0.002	0.97	0.99
Baecke work (range: 1–5)	0.98	0.27	0.95	1.02	1.01	0.67	0.98	1.03
Baecke sport (range: 1–5)	1.01	0.69	0.96	1.06	0.99	0.65	0.96	1.03
Baecke leisure time (range: 1–5)	1.05	0.05	1.00	1.11	1.01	0.74	0.97	1.04
Time point	1.07	0.05	1.00	1.15	1.05	0.12	0.99	1.10

CI: confidence interval; eMET: estimated metabolic equivalent of task; HADS: Hospital Anxiety and Depression Scale.

portant Difference (MCID) of the 6-minute walk test distance was established at 25 m after a cardiac rehabilitation programme for patients with coronary artery disease [37]. Therefore, the improvement in the 6-minute walk test after cardiac rehabilitation in our study is clinically meaningful. Similarly, the median scores of eMET increased by 0.9 points from entry to discharge in our study, which exceeds the proposed 0.5-MET improvement of the Canadian Cardiovascular Society [38]. To the best of our knowledge, the MCID for the maximal short-term exercise capacity in cardiac rehabilitation patients has not been proposed. However, for adults with chronic musculoskeletal pain, its threshold was established at 25–55 W [39]. We found an increase of 50 W in the median scores of maximal short-term exercise capacity at discharge, which falls within this range.

The median scores of maximal quadriceps isometric strength also showed improvement after cardiac rehabilitation, with an increase between 3 and 4 Nm (7% to 9% from baseline). The MCID for the maximum quadriceps isometric strength (+5.7 Nm) has been described in patients with chronic obstructive pulmonary disease [40]. The quadriceps strength is known to be a predictor of walking performance, exercise capacity [41] and cardiovascular mortality in patients with coronary artery disease [42]. Accordingly, each 10% increase in body weight-adjusted maximal quadriceps isometric strength is associated with reductions of 23% and 34% in the risk of all-cause and cardiovascular mortality, respectively. The observed gains in walking and exercise performance (clinical significance) together with muscle strength could lead to increased independent mobility and more favourable outcomes in our patients. Previous studies showed that every 10 m increase in 6-minute walk test is associated with a 4% reduction in mortality [43], and each 1-MET increase is associated with a 19% lower cardiovascular mortality risk among patients with cardiovascular diseases [44].

The PROMs were also improved from entry to discharge and from entry to the 6-month follow-up. The median depression and anxiety scores decreased significantly during follow-up (between –0.5 and –1 point from entry) but lower than the proposed MCID of 1.7 points [45]. These results can be expected because the participants have a low Hospital Anxiety and Depression Scale (HADS) score at baseline. In addition to psychological improvement, leisure-time physical activity increased and remained elevated at 6 months. A previous meta-analysis of 40 randomised controlled trials showed moderate evidence of increased physical activity after cardiac rehabilitation participation compared with controls [11]. Changes in scores for the work and sport physical activity were not statistically significant during follow-up, probably because our participants were too old (median age of 63 years) to return to work. The median scores of quality of life improved from entry to 6 months after discharge, with a greater difference in the physical domain (+6 points) than in the emotional domain (+2 points). These results are consistent with a previous literature review demonstrating improved quality of life after cardiac rehabilitation in patients with coronary heart disease [8, 46]. There is some evidence that the positive effects of cardiac rehabilitation on physical activity might decrease at longer follow-up [47]. Therefore, ongoing encouragement of a healthy lifestyle and sustained

physical activity beyond the initial period of cardiac rehabilitation is necessary.

Factors associated with the heart-related quality of life were the 6-minute walk test and the levels of depression and anxiety. Our findings confirm the results of previous studies that demonstrated functional capacity and psychological distress as predictors of quality of life [14–16]. The association coefficients of some predictors were weak or moderate, for example, the 6-minute walk test (coefficient: 1.001) or symptoms of anxiety (coefficient: 0.97) or depression (coefficient: 0.95). Therefore, there may have been other potential factors influencing heart-related quality of life (such as comorbidities, quality of sleep, social background, etc.) that warrant examination in future studies.

The rate of participation in our cardiac rehabilitation programme was very high (99%). The interval between the acute hospitalisation and rehabilitation phase was also short (1.4 months). In the literature, the overall participation rate in cardiac rehabilitation programmes by patients with acute myocardial infarction is low (34%) [48]. Inadequate referral or geographic variation by hospital referral might be barriers to participation in a cardiac rehabilitation programme [49]. A high rate of participation in our study might be explained by the geographic convenience, the effectiveness of the liaison between the hospital and rehabilitation centres and information on the cardiac rehabilitation programme. Another study showed that cardiac rehabilitation participation rates were associated with insurance status [50]. All Swiss residents are covered under a mandatory universal basic health insurance that includes outpatient and inpatient treatments in a fee-for-service system [51]. The health insurer's basic insurance pays for in- or outpatient rehabilitation programmes.

Women accounted for 19% of the studied population. Previous studies conducted in the Netherlands, in Italy and in Taiwan also noted a low percentage of women (28%, 27% and 23%, respectively) in cardiac rehabilitation [52–54]. Many reasons for low participation in cardiac rehabilitation by women have been described including lack of insurance or information, transportation issues, long distance, lack of support, comorbidities, older age and obesity [55]. Future studies aiming to increase the participation of women in cardiac rehabilitation programme are needed.

Strengths and limitations

This study has several limitations. It was conducted at a single clinic which might induce population bias. For instance, most participants were men (81%), with a median age of 63 years which limits the generalisability of the results to other populations. There was also a fraction of missing data from the self-reported questionnaires, despite a second reminder to participants to return their responses. The missing data might potentially lead to attrition bias. Data on functional capacity at 6 months are unavailable, so we are unable to determine its progression over time. Another limitation is the absence of a randomised control group which means the improvement of outcomes may have been influenced by the natural course of recovery.

The strength of our study lies in the use of both objective and patient-reported measures to assess outcomes. The

functional measurements (6-minute walk test, maximal short-term exercise capacity, eMET, quadriceps isometric strength) were performed using standardised procedures and validated instruments to minimise the measurement bias. PROMs (psychosocial aspect and physical activity) were assessed at different time points. Additionally, we used multilevel mixed-effects generalised linear models to assess the predictors of HeartQoL, adjusting for age, sex and time points. This approach enhances statistical power and provides a basis for predictive modelling.

Conclusions

Functional capacity measures including the 6-minute walk test, maximal short-term exercise capacity, eMET and muscle strength increased significantly at discharge from cardiac rehabilitation. Improvements in the 6-minute walk test and eMET were considered clinically meaningful. The level of depression and anxiety, quality of life and leisure-time activity showed significant improvement from entry to discharge and from entry to 6 months. The 6-minute walk test, and the symptoms of depression or anxiety were found to be significantly associated with quality of life. A cardiac rehabilitation programme could be proposed to eligible cardiac patients to improve their outcomes.

Data sharing statement

The database was registered on Mendeley Data. Analytical codes will be made available on request.

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Potential competing interests

All authors have completed and submitted the International Committee of Medical Journal Editors form for disclosure of potential conflicts of interest. No potential conflict of interest related to the content of this manuscript was disclosed.

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Supplement Table S1: Functional capacity at entry and discharge from the cardiac rehabilitation program in two groups (ACS±PCI vs other etiologies)

	N	Entry Median, IQR	Discharge Median, IQR	Value changes Median, 95%CI	p-value*
ACS±PCI					
6MWT (m)	207	560 (510-610)	630 (575-670)	60 (50-65)	<0.001
MSEC (W)	207	225 (175-275)	275 (200-325)	50 (50-50)	<0.001
Maximal left QIS (Nm)	170	44 (34-53)	49 (39-57)	3 (2-4)	<0.001
Maximal right QIS (Nm)	170	46 (34-57)	51 (41-59)	3 (2-4.3)	<0.001
eMET	170	8.4 (6.6-10.6)	10.2 (7.4-11.2)	0.9 (0.7-1.1)	<0.001
Other etiologies					
6MWT (m)	66	545 (500-610)	620 (540-685)	60 (45-75)	<0.001
MSEC (W)	66	200 (125-250)	250 (200-325)	50 (50-75)	<0.001
Maximal left QIS (Nm)	53	41 (33-50)	44 (37-53)	3 (2-7)	<0.001
Maximal right QIS (Nm)	53	40 (34-51)	47 (35-56)	4 (2.9-7)	<0.001
eMET	53	7.9 (5.9-10.6)	9.5 (7.1-11.7)	1 (0.4-1.5)	<0.001

6MWT: 6-min walk test; MSEC: maximal short-term exercise capacity measurement; QIS: quadriceps isometric strength; eMET: estimated metabolic equivalent of task, CI: confidence interval, IQR= Interquartile range; *: Wilcoxon signed-rank tests; ACS ±PCI: acute coronary syndrome with or without percutaneous coronary intervention

Supplement Table S2: Patient-reported outcome measures of depression and anxiety, quality of life and physical activity during the 6-month follow-up in two groups (ACS±PCI vs other etiologies)

			Entry	Discharge	6-month	Kruskal-Wallis
			n	Median (IQR)	Median (IQR)	p-value
ACS±PCI						
HADS	Depression	160	6 (4-9)	4 (3-7)	5 (3-7)	<0.001
	Anxiety	160	5 (4-7)	4 (3-6)	4 (2-7)	<0.001
HeartQoL	Physical	143	19 (15-24)	24 (20-27)	24 (19-27)	<0.001
	Emotional	143	9 (7-11)	11 (9-12)	11 (9-12)	<0.001
Baecke	Work	140	2.4 (1-3.4)	2.6 (1.4-3.5)	2.1 (1-3)	0.05
	Sport	140	2.5 (2-3.5)	2.8 (2-3.5)	3 (2-3.5)	0.20
	Leisure	140	3 (2.5-3.3)	3 (2.7-3.7)	3.2 (2.7-3.7)	0.006
Others						
HADS	Depression	52	5 (3-8)	4 (2-8)	4 (2-7)	0.21
	Anxiety	52	5 (3-7)	4 (2-6)	4 (3-7)	0.50
HeartQoL	Physical	52	18 (15-23)	25 (21-18)	25 (20-27)	<0.001
	Emotional	52	10 (8-12)	12 (9-12)	11 (8.5-12)	0.08
Baecke	Work	52	2.4 (1-3.3)	2.5 (1.6-3.4)	2.6 (1-3.5)	0.78
	Sport	52	2.5 (2.3-3.5)	2.8 (2.1-3.4)	2.8 (2-3.5)	0.62
	Leisure	52	3 (2.3-3.5)	3 (2.7-3.5)	3.2 (2.3-3.6)	0.68

HADS: Hospital Anxiety and Depression Scale, IQR: interquartile range

ACS ±PCI: acute coronary syndrome with or without percutaneous coronary intervention