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Examination of Clinical and Psychosocial Determinants of Exercise Capacity Change in Cardiac Rehabilitation

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Abstract

Purpose—Most cardiac rehabilitation (CR) completers improve in multiple functional and psychosocial domains. However, not all demonstrate uniform improvement in functional indicators such as exercise capacity. This study examined baseline predictors and correlates of change in exercise capacity from CR intake to completion.

Methods—CR participants (n=488) completed assessment of metabolic equivalents (METs) via treadmill stress test, depressive symptoms, quality of life, and social support at intake and discharge. Associations between demographic, clinical, and psychosocial factors and MET changes was tested with linear regression.

Results—METs increased from intake to discharge (1.91±1.48, p<.001). Younger age (p<.001), lower BMI (p<.001), and lower weight (p<.01) were associated with greater MET change. Greater

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percentage weight loss ($p<.05$), and self-reported improvements in physical functioning ($p<.001$) and bodily pain ($p<.01$) were concurrently related to MET change.

Conclusions—Older CR attendees and those with higher baseline BMI may benefit from tailored intervention to ensure maximum benefit in exercise capacity.

Keywords

exercise capacity; cardiac rehabilitation; metabolic equivalents

Introduction

Increased cardiorespiratory fitness and functional capacity are primary goals of cardiac rehabilitation (CR). Comprehensive phase II CR offers intensive lifestyle interventions that typically include 36 sessions over 12 weeks of monitored exercise, nutrition education, and stress management training under the supervision of a multidisciplinary team.[1] Substantial evidence documents the benefits of CR on cardiovascular outcomes[1] and psychological functioning.[2]

Directly measured or estimated cardiorespiratory fitness is a vital component of clinical assessment.[3,4] Most patients complete an exercise stress test at CR initiation and completion and demonstrate improved exercise capacity at CR discharge. Improvements vary and can be modest or absent after CR,[5] which may limit effects on cardiovascular and all-cause mortality.[6] When exercise capacity is assessed via metabolic equivalents of tasks (METs), meta-analytic aggregation reports average improvements of 1.55 METs.[7] Patients whose maximal exercise capacity is below 3.5 METs at CR discharge are at higher risk for myocardial infarction, heart failure-hospitalization, and all-cause mortality with 1- and 3-year event rates of ≥7 and ≥18%, respectively.[8] It is important to understand the baseline risk factors of patients likely to achieve limited improvements in exercise capacity.

Patients with these risk factors may fare worse than those without even if they complete CR. Given that psychosocial risk factors like low social support, depression, anxiety, and poor quality of life indicate suboptimal outcomes,[9–12]However, heterogeneity in MET improvement’s psychosocial determinants have been under-studied compared to number of sessions, program type, and baseline fitness.[7] CR programs would benefit from increased understanding of MET improvement’s psychosocial correlates. One of the few prior studies examining psychosocial correlates of cardiorespiratory fitness improvements reported that hostility and depressive symptoms predicted less improvement in cardiorespiratory fitness assessed via peak oxygen consumption following 36 CR sessions.[5] Composite psychosocial stress improvement, but not anxiety, hostility, and depression examined separately, was lower in those whose cardiorespiratory fitness did not improve.[5] Whether other baseline factors (e.g., low social support or quality of life) or changes in these variables are associated with less exercise capacity improvement following CR is unknown. The purpose of the present study was to utilize registry data from an American Association of Cardiovascular and Pulmonary Rehabilitation (AACVPR) accredited CR to determine baseline predictors and correlates of improved exercise capacity in CR completers. We hypothesized that being less depressed, having more social support, and having better health-related quality of life would be associated with greater improvements in exercise capacity at CR discharge. We also explored correlates of change in exercise capacity.

Material and methods

Participants

The present study was a retrospective review of medical records and AACVPR registry data. The initial sample consisted of 650 CR attendees who enrolled an AACVPR-accredited comprehensive CR program in Providence, RI. For the present analyses, attendees who enrolled and completed ≥18 sessions between October 1, 2014 and June 27, 2016 were included. CR completers were selected to understand variability in outcomes for individuals receiving a sufficient dose of treatment to demonstrate improvements. Individuals who unexpectedly terminated enrollment were unlikely to have completed discharge assessments. Individuals were admitted to the program following physician referral for admission diagnoses of angina, CABG, heart failure, non ST-elevation myocardial infarction (NSTEMI), ST-elevation myocardial infarction (STEMI), valve repair/replacement, and percutaneous coronary intervention (PCI). Attendees with the following uncommon CR admission event diagnoses were excluded from the present analysis: cardiac transplant (n = 2), transcutaneous valve implantation (n = 3), and ventricular assist device/artificial heart (n = 1), and those with no diagnosis listed (n = 7). Six-hundred and thirty-seven enrollees met the inclusion criteria. Complete case analyses were performed. Participants were excluded based on missing data, included baseline METS (n = 59) and discharge METS (n = 90). This resulted in a final sample of 488 individuals.

Measures

Demographic, medical, and clinical information were collected through the CR program in accordance with AACVPR guidelines at program intake and discharge. METS were determined from a treadmill stress test administered using a Bruce or modified Bruce protocol.[13–15]

Additional measures completed at baseline and discharge included the following:

1. The *Patient Health Questionnaire—9* (PHQ-9).[16] The PHQ-9 is a 9-item tool that assesses depressive symptoms. The total PHQ-9 score was used in analyses as a continuous variable, with higher scores indicating higher levels of depressive symptoms.
2. *ENRICHD Social Support Instrument* (ESSI).[17] The ESSI is a 7-item social support questionnaire. The total ESSI score was used, where higher scores indicate higher self-reported social report.
3. *Rand 36-Item Short Form Survey* (Rand-36).[18] The Rand-36 is a 36-item questionnaire with 8 subscales that measures a variety of aspects of health-related quality of life. Subscales include physical functioning, physical role functioning, emotional role functioning, energy/fatigue, emotional well-being, social functioning, pain, and general health. Higher scores reflect better functioning.

Procedure

Institutional review board approval was obtained to conduct a retrospective chart review of clinical records. As part of the CR intake process, all patients completed a comprehensive baseline assessment of demographic and medical history, and psychosocial and physical functioning. Following intake, patients are generally advised to attend 3 sessions each week for 12 weeks. CR completion was defined as completion of ≥18 sessions because some patients completed a shorter program duration (i.e., < 36 sessions, but not < 18 sessions) due to insurance reimbursement restrictions. CR participants completed monitored exercise training and attended psychoeducational lectures that target cardiac conditioning, stress management, nutrition education, and behavior modification. During monitored exercise sessions, attendees are instructed to exercise at 50–70% of measured heart rate reserve, 70–85% of maximum heart rate, or based on perceived exertion (3–5/10 or 11–13/20). At the time of program completion, patients completed a final assessment of physical and psychosocial functioning.

Data analysis

Descriptive statistics were calculated to characterize the sample. To examine predictors of MET change, several hierarchical multiple linear regressions were run. First, associations between baseline demographic/medical variables and MET change were examined. In each regression, Block 1 included the number of sessions attended. Block 2 included each candidate covariate entered alone. The following were examined as candidate covariates: age, gender, minority status (minority vs. non-Hispanic Caucasian), and intake tobacco use status (never/former smoker vs. current smoker). The presence of the following comorbidities were also examined: diabetes, renal disease, pulmonary disease, cerebrovascular disease, cancer, and peripheral artery disease. Variables that accounted for ≥1% of the variance (i.e., corresponding to a small effect size, R^2 change > .01) in MET change after controlling for the number of completed sessions were included as covariates in subsequent models.

Second, regression models were conducted to examine baseline predictors of MET change. Baseline scores were entered into Block 2 after controlling for the number of sessions completed, and covariates in Block 1. As above, variables that explained ≥ 1% of the variance in MET change after controlling for the number of sessions completed and covariates were considered relevant.

Exploratory analyses of psychosocial correlates of MET improvement were also performed. Change scores were created by calculating the difference of the intake and discharge scores for all psychosocial and clinical variables that were assessed at both intake and discharge. In a series of linear regression models, Block 1 included number of sessions completed, and baseline covariates. Block 2 included MET change scores. Analyses were conducted using IBM© Statistical Package for the Social Sciences (SPSS©) version 20.0 statistical software (IBM Corporation).

Results

Sample

The final sample consisted of 370 men and 118 women who completed ≥ 18 CR sessions as well as intake and discharge MET assessment. Nearly 95% of the sample (n = 461) identified as non-Hispanic Caucasian. The most common admission events included PCI, STEMI, and non-STEMI. Approximately 55% of participants (n = 267) participants completed 35 – 36 sessions. See Table 1 for detailed sample characteristics.

Baseline predictors of MET improvement

METs improved an average of 1.91 ± 1.48 points following CR completion ($t(487) = -28.65$, $p < .001$). There was a small correlation between baseline METs and MET change ($r = -.15$, $p < .001$). Baseline MET scores explained 68.2% of the variability in discharge MET scores ($F(1, 486) = 1038.61$, $p < .001$), with higher intake scores predicting higher discharge scores ($\beta = .83$, $p < .001$). Controlling for the number of completed sessions, demographic and medical predictors of less MET change included older age, ($\Delta R^2 = .04$, $\beta = -.210$, $p < .001$) and diabetes ($\Delta R^2 = .01$, $\beta = -.110$, $p < .05$), but not gender, minority status, smoking status, history of cancer, renal disease, peripheral artery disease, cerebrovascular disease, or previous MI.

After controlling for the number of completed sessions, age, and diabetes, higher baseline BMI was related to less change in METs ($\Delta R^2 = .030$, $\beta = -.05$, $p < .001$). A similar pattern emerged between higher weight at intake and less MET improvement ($\Delta R^2 = .018$, $\beta = -.14$, $p < .01$). Baseline depressive symptoms, social support, bodily pain, physical functioning, physical role functioning, vitality, emotional role functioning, emotional well-being, general health, and social functioning were not associated with MET change (Table 2).

Changes in psychosocial variables as correlates of MET improvement

Improvements in self-reported Rand-36 physical functioning was related to MET improvement ($\Delta R^2 = .04$, $\beta = .20$, $p < .001$) with number of completed sessions, age, and diabetes entered as covariates. Improvements in bodily pain were also related ($\Delta R^2 = .02$, $\beta = .14$, $p < .01$). Finally, a small association emerged between greater percentage weight loss and MET improvement ($\Delta R^2 = .01$, $\beta = -.11$, $p < .05$). Changes in depressive symptoms,[1] social support, physical role functioning, emotional role functioning, general health, social functioning, emotional well-being, vitality, and BMI were not related to MET change after accounting for number of completed sessions, age, and diabetes. See Table 2.

Comparison of predictors of METs in men versus women

A similar series of analyses was conducted post-hoc that examined whether baseline predictors or improvements in psychosocial variables differed between men and women. Though men demonstrated higher discharge METs compared to women (8.9 ± 2.65 versus

[1]We previously reported the relationship between MET change and change in depressive symptoms in Gathright et al. (in press). The relationship was also included here in order to report all data relevant to the current research question.

7.5 ± 2.09), MET improvement did not differ between men and women over the course of CR. No differing associations between demographic, medical, or clinical variables and MET change emerged. Similarly, relationships between improvements in psychosocial variables and METs did not differ between men and women.

Discussion

The present study examined baseline predictors and correlates of MET improvement in a retrospective analysis of CR completers. Small associations emerged between younger age, lower baseline weight, lower baseline BMI and greater increases in METs. Greater improvements in self-reported physical functioning, bodily pain, and weight were also associated with greater change in METs. Surprisingly, contrary to our hypotheses, changes in other psychosocial factors thought to be indicators of improvement in physical and psychological health were not related to MET improvement.

Prior research has indicated that heart failure patients with high fitness demonstrate better prognosis regardless of BMI status.[19] Consistent with our findings, a large, recent retrospective analysis also reported that individuals with higher BMI experienced less improvement in exercise capacity following CR.[20] CR patients with excess weight at intake may require additional resources to support greater improvements in exercise capacity and associated prognostic benefit. Interestingly, percent weight change, but not BMI change, was related to MET improvement. Prior research indicates that weight losses of at least 5% in obese CR patients are associated with improved METs, HDL, LDL, total cholesterol, and triglycerides.[21] Overall, Lavie and Milani (1997) reported that obese patients demonstrated a 27% increase in METs compared to a 39% increase in non-obese patients following CR participation.[21] Importantly, obese individuals who demonstrated ≥ 5% weight reduction had a 34% increase in METS compared to a 26% increase in obese individuals who did not demonstrate ≥ 5% weight reduction.[21] In post-hoc examination of the current sample following BMI criteria used by Lavie and Milani,[21] individuals who were obese at baseline with a ≥ 5% weight loss demonstrated a 41% increase in METs. Individuals who were obese at baseline who did not demonstrate at least a 5% weight reduction had a MET increase of 30%. Small BMI change in the current sample may have reduced the ability to detect an association between BMI reduction and increased exercise capacity; percent weight change may present a more sensitive metric of weight reduction compared to continuous BMI change in the current study. Given that the effect of the association between percentage weight loss and MET improvement was small, replication of the current findings is warranted. Prospective studies of purposeful weight loss in CR patients with additional metrics of adipose tissue distribution are needed to better understand whether weight loss in CR attendees is necessary to achieve maximal benefits.

The present finding that self-reported physical functioning and bodily pain improved alongside MET improvements, but not other aspects related to physical and psychosocial function concurs with a recent report that METs were weakly correlated with health-related quality of life.[22] CR attendees may notice improvements in pain and physical functioning, including common activities such as walking, bathing, dressing, carrying groceries, and climbing stairs, more readily than other, more nuanced concepts related to physical functioning. For example, individuals may notice improvements in comfort or ability during exercise over the course of CR, and attribute this to better physical functioning. In addition, we recently reported that improvement in bodily pain was associated with improvement in depressed mood at the time of CR completion[23]; improved bodily pain may encourage more physical activity and associated MET improvement. Conversely, individuals may be less apt to quickly recognize direct impacts of their ability to complete work or related tasks. If changes in other areas do occur, they may develop or be noticed more slowly. However, these possibilities need empirical examination. Given that improved METs may not always improve in conjunction with self-reported health status or health-related quality of life, CR professionals should evaluate patients using both objective and subjective assessments when possible. This recommendation is consistent with existing literature suggesting that disease severity should be measured with both objective and subjective tests specifically when evaluating CVD patients due to improved disease severity being minimally related to self-reported quality of life.[24]

Limitations of the present study warrant mention. First, the lack of comparison with individuals who did not enroll in or complete CR may have led to a lower proportion of individuals who present the greatest risk for limited improvement. It is possible that individuals who completed the course of CR have higher physical and psychosocial functioning compared with non-completers. Future research is needed to directly compare the improvements with exercise capacity over a similar timespan in non-completers and to explore whether improvements in exercise capacity relate to improved psychosocial functioning over a longer period of assessment. In addition, our findings should be interpreted in light of the inclusion of individuals completing 18 to 36 sessions, as unexamined influential factors may exist between individuals who completed a shorter CR protocol. Second, the present sample included only a small proportion of individuals with METS < 3.5 at discharge (< 5%). In contrast with prior research suggesting greater MET improvements in men,[25,26] men in our sample did not demonstrate greater MET improvement than women. Mean MET change for men was somewhat lower than what is reported elsewhere,[25] whereas MET improvement in women was slightly higher. A sample with greater variability in discharge METs may reveal different findings. Third, estimation of peak exercise capacity through use of METs as opposed to directly determined VO_{2peak} represents a potential limitation. Replication of the present findings in a sample with directly measured VO_2 would be of benefit. Finally, the current findings may be biased by assessment of participants from only one CR program, and the inclusion of primarily Caucasian males. Additional research is needed to assess the current findings in a sample consisting of greater proportion of women and individuals of diverse racial and ethnic backgrounds.

Conclusions

The present findings highlight that individuals who enter CR with varying demographic, medical, and psychosocial risk factors for poor outcomes can glean benefit in exercise capacity from CR completion. Although many patients entered CR with varying risk, improvements in self-reported physical functioning, bodily pain, and weight were associated with greater change in exercise capacity assessed via METs. When possible, CR attendees may benefit from CR staff-initiated screening of self-reported physical functioning and bodily pain to address any modifiable barriers that would prevent maximal benefit from monitored exercise training during CR. Future research on whether bodily pain or excess weight represents a barrier to CR engagement is greatly needed, given that pain may interfere with participants' ability to exercise at an intensity that matches their cardiorespiratory fitness capacity. CR patients with obesity and those who report pain or low physical functioning may benefit from increased tailoring of CR, such as incorporation of supplemental, alternative forms of exercise (e.g., hydrotherapy, tai chi).

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Table 1.

Characteristics of Participants (*N* = 488)

	Total Sample *M* ± *SD* or *n*(%)
Demographic and Medical	
Age	62.44 ± 10.94
Female	118 (24.2)
Non-Hispanic Caucasian	461 (94.5)
Comorbidity	
Cancer	30 (6.1)
Cerebrovascular Disease	14 (2.9)
Type 2 Diabetes	109 (22.3)
Peripheral Artery Disease	24 (4.9)
Previous Myocardial Infarction	26 (5.3)
Pulmonary Disease	54 (11.1)
Renal Disease	37 (7.6)
Baseline METs	6.48 (2.42)
Baseline BMI	30.58 (5.62)
Admission Event	
Angina	12 (2.5)
CABG	67 (13.7)
Heart Failure	24 (4.9)
NSTEMI	89 (18.2)
STEMI	117 (24.0)
PCI	121 (24.8)
Valve repair/replacement	58 (11.9)
Number of sessions attended	33.05 (4.08)

Note. METs = metabolic equivalents, CABG = coronary artery bypass grafting; NSTEMI = non-ST-elevation myocardial infarction; STEMI = ST-elevation myocardial infarction; PCI = percutaneous coronary intervention.

Table 2.

Predictors of MET change.

	METs		
	ΔR^2	*b (SE)*	β
Demographic/Medical Factors[a]			
Number of sessions attended	.002	.015 (.017)	.042
Age	.044***	−.028 (.006)***	−.210***
Gender	.002	−.145 (.154)	−.042
Minority Status	.001	−.253 (.287)	−.023
Tobacco Use	.000	−.006 (.137)	−.002
Diabetes	.012*	−.374 (.169)*	−.110*
Renal Disease	.002	−.277 (.254)	−.050
Pulmonary Disease	.003	−.269 (.215)	−.057
Cerebrovascular Disease	.001	−.325 (.403)	−.037
Cancer	.000	−.015 (.285)	−.002
Peripheral Artery Disease	.004	−.416 (.305)	−.062
Psychosocial and Clinical Factors at Baseline[b]			
PHQ-9	.000	−.005 (.018)	−.013
ESSI	.000	.006 (.015)	.022
Rand-36 Physical Functioning	.001	.002 (.003)	.036
Rand-36 Energy/Fatigue	.004	.004 (.003)	.059
Rand-36 Role Physical Functioning	.000	.001 (.002)	.017
Rand-36 Bodily Pain	.001	.002 (.003)	.024
Rand-36 General Health	.006	.006 (.004)	.081
Rand-36 Social Functioning	.000	.000 (.003)	.004
Rand-36 Role Emotional Functioning	.000	.000 (.002)	−.003
Rand-36 Emotional well-being	.000	.001 (.004)	.011
BMI	.030***	−.049 (.014)***	−.179***
Weight	.018*	−.012 (.004)*	−.140*
Changes in Predictors[b]			
Δ ESSI	.003	−.020 (.020)	−.050
Δ PHQ-9	.000	−.009 (.024)	−.018
Δ Rand-36 Physical Functioning	.039***	.015 (.004)***	.200***
Δ Rand-36 Vitality	.007	.006 (.004)	.082
Δ Rand-36 Role Physical Functioning	.003	.002 (.002)	.056
Δ Rand-36 Bodily Pain	.019**	.009 (.003)**	.138**
Δ Rand-36 General Health	.004	.007 (.005)	.062
Δ Rand-36 Social Functioning	.003	.004 (.003)	.055
Δ Rand-36 Role Emotional Functioning	.000	.001 (.002)	.018
Δ Rand-36 Emotional well-being	.000	.001 (.005)	.009

	METs		
	ΔR^2	*b (SE)*	β
Δ BMI	.008	−.135 (.074)	−.090
% Δ Weight	.011 *	−.051 (.024) *	−.106 *

Note. METS = metabolic equivalents; PHQ-9 = Patient Health Questionnaire-9; ESSI = Enhancing Recovery in Coronary Heart Disease Social Support Inventory; Rand-36 = 36-item Short Form Health Survey; BMI = body mass index.

[a]Analyses controlled for number of sessions completed, with the exception of regression examining number of sessions completed as the predictor of interest

[b]Analyses controlled for number of sessions completed, age, and diabetes.

*$p < .05$

**$p < .01$

***$p < .001$