Diabetes, Metabolic Syndrome and Obesity Dovepress

Open Access Full Text Article ORIGINAL RESEARCH

Change in Cardiometabolic Health Following Participation in Cardiac Rehabilitation for Coronary Heart Disease: Effect Modification by Metabolic Syndrome Status

Joshua Garfein[1], Elizabeth A Gnatiuk[1,2], Eric J Brandt[1,3], Chih-Wen Pai[1], Joseph Bryant[1], Eva Kline-Rogers[1], Samantha Fink[1], Melvyn Rubenfire[1]

[1]Division of Cardiovascular Medicine, Department of Internal Medicine, University of Michigan, Ann Arbor, MI, USA; [2]Experimental Medicine Program, Faculty of Medicine, University of British Columbia, Vancouver, BC, Canada; [3]Institute for Healthcare Policy and Innovation, University of Michigan, Ann Arbor, MI, USA

Correspondence: Melvyn Rubenfire, Division of Cardiovascular Medicine, Department of Internal Medicine, University of Michigan, 24 Frank Lloyd Wright Dr, Lobby A., Ann Arbor, MI, 48106-0363, USA, Tel +1 734 998 7411, Fax +1 734 998 7456, Email mrubenfi@med.umich.edu

Objective: To investigate changes in cardiometabolic risk factors after completion of cardiac rehabilitation (CR) for coronary heart disease (CHD) and ascertain whether the magnitude of improvement in cardiometabolic health differs between those with and without metabolic syndrome (MetS).

Methods: In this observational cohort study, data were analyzed from 1984 patients enrolled in CR at the University of Michigan between 2011-01-01 and 2020-02-29 for the indication of CHD. Patient characteristics were collected from standardized health questionnaires and during CR intake evaluations. Cardiometabolic biomarkers were recorded from baseline laboratory data and re-examined upon completion of CR. Differences in baseline patient characteristics by MetS status were compared using chi-square tests. Wilcoxon rank-sum tests were used to compare baseline differences, and signed-rank tests were used to evaluate the change in variables between baseline and completion of CR. The difference of change by MetS status was assessed using difference-in-differences regression models.

Results: Of the 1984 patients, 1070 (53.9%) met the criteria for MetS at baseline, of which 770 were male (72.0%). Those with MetS lost 1.43 pounds more (95% CI: 0.56, 2.31, $P = 0.001$), experienced a 0.21 larger drop in body mass index (95% CI: 0.03, 0.37, $P = 0.02$), and had a 0.31 greater reduction in waist circumference (95% CI: 0.08, 0.54, $P = 0.008$). Difference-in-differences regression models revealed those with MetS experienced a greater reduction in triglycerides and fasting glucose, with a difference of change of −8.70 for triglycerides (95% CI: −15.04, −2.37, $P = 0.007$) and −5.48 for glucose (95% CI: −10.44, −0.53, $P = 0.03$). There was no significant difference in the change in HDL-C or LDL-C for MetS status.

Conclusion: Compared to those without MetS, patients with MetS experienced a comparable or greater benefit from CR, particularly with respect to improvements in MetS components.

Keywords: chronic disease management, coronary heart disease, cardiometabolic risk factors, cardiovascular disease

Introduction

Metabolic syndrome (MetS) is characterized by a clustering of risk factors for cardiovascular disease (CVD) and diabetes mellitus (DM).[1–3] Criteria for the clinical diagnosis of MetS commonly include the presence of at least three of the following five factors: abdominal obesity, elevated triglycerides, low high-density lipoprotein (HDL) cholesterol, hypertension and impaired fasting blood glucose.[4,5] The overlapping of these conditions contribute substantially to morbidity and mortality, particularly due to increased risk of DM[1] and CVDs such as coronary heart disease (CHD), heart failure (HF), and stroke.[2,6]

Received: 24 May 2024
Accepted: 12 October 2024
Published: 26 November 2024

© 2024 Garfein et al. This work is published and licensed by Dove Medical Press Limited. The full terms of this license are available at https://www.dovepress.com/terms.php and incorporate the Creative Commons Attribution – Non Commercial (unported, v3.0) License (http://creativecommons.org/licenses/by-nc/3.0/). By accessing the work you hereby accept the Terms. Non-commercial uses of the work are permitted without any further permission from Dove Medical Press Limited, provided the work is properly attributed. For permission for commercial use of this work, please see paragraphs 4.2 and 5 of our Terms (https://www.dovepress.com/terms.php).

Cardiac rehabilitation (CR) is a comprehensive, evidence-based program designed primarily for secondary prevention of CVD. Robust literature supports the use of CR as a cost-effective intervention for individuals with a variety of cardiovascular conditions, with associated improvements in quality of life, morbidity, and mortality.[3] Available evidence suggests that CR improves MetS, including each of its components.[7] Previous research has indicated that it may be intrinsic factors, such as age, sex, or body mass index (BMI) that determine the level of functional improvement in patients undergoing CR,[8] and other studies have found that CR is associated with smaller improvements in cardiometabolic health among those with DM (particularly type II) than among those without.[9,10] However, whether MetS modifies the impact of CR on cardiometabolic health remains unclear.

In this study, we investigated changes in cardiometabolic risk factors from before to after the completion of CR in individuals with CHD and compared these changes amongst those with or without MetS identified at baseline. We hypothesized that cardiometabolic health would improve following CR with the indication related to CHD and that the magnitude of improvement would be greater in MetS.

Material and Methods

Patients

In this observational cohort study, we utilized the comprehensive data from 1984 patients enrolled in the University of Michigan CR program between 2011-01-01 and 2020-02-29 whose indication for CR was CHD-related. Eligible qualifying diagnoses included myocardial infarction (MI) with or without percutaneous coronary intervention (PCI), PCI, coronary artery bypass graft (CABG) surgery, and stable angina (Figure 1). The University of Michigan IRB approved this study (IRB#: HUM00045929, approved 2011–04-21). We obtained consent to participate in CR and use of patient data for research purposes from all participants at the time of CR enrollment.

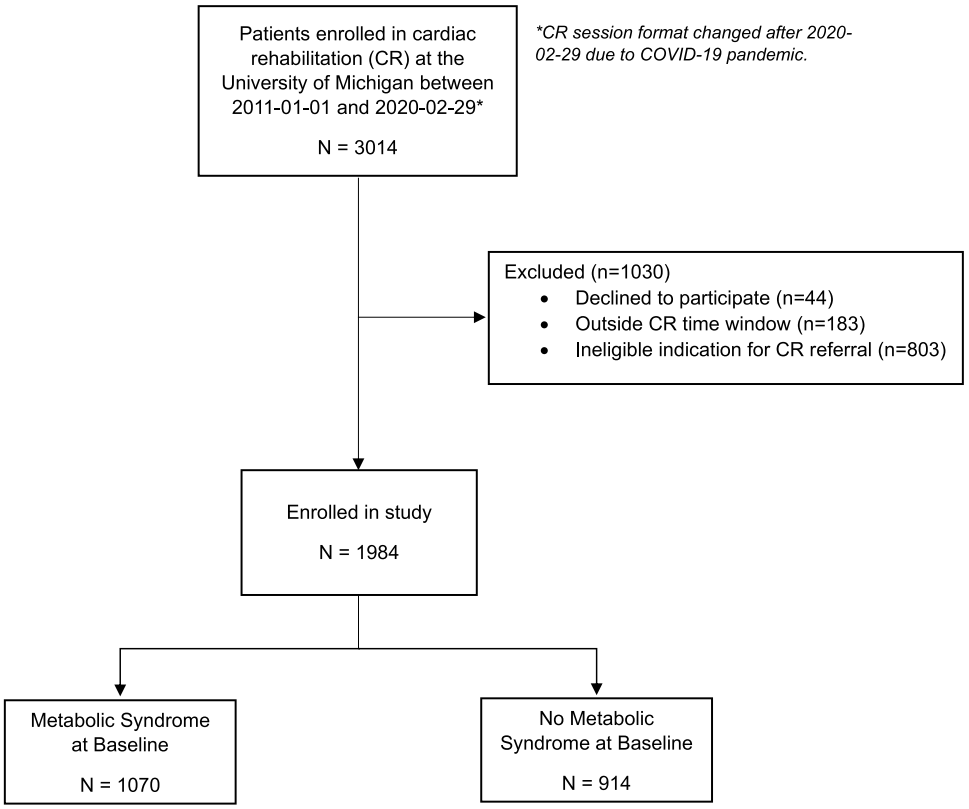

Figure 1 Study flow chart.

Data

The study data were analyzed retrospectively utilizing the same research methods and University of Michigan CR participant sample as the study conducted by Brandt et al (2023), which investigated the prevalence of factors among patients with CHD that may be considered low-risk for participation in alternative CR models.[11] Self-reported patient characteristics, including age, sex, race, ethnicity, physical activity, smoking status, and history of peripheral arterial disease were collected from standardized health questionnaires and intake evaluation by an exercise physiologist. Comorbidities were derived from past diagnostic codes including stroke, heart failure, peripheral vascular disease, chronic obstructive pulmonary disease (COPD), diabetes, hypertension, atrial fibrillation or flutter, and presence of cardiac pacemaker or implantable cardioverter defibrillator. We defined angina based on the indication for referral validated by the exercise physiologist at the time of CR entry. Psychological distress was assessed by the Brief Symptom Inventory (BSI), consisting of 53 items that cover nine symptom dimensions of which we used four in our studies in CR (depression, hostility, anxiety, and global severity index).[12]

Metabolic biomarkers were obtained from participants' health records from the date closest to baseline CR evaluation and collected again upon completion of CR. Resting blood pressure was measured via the American Heart Association guidelines using regularly calibrated oscillometric devices with patient sitting upright and forearm supported at the level of the heart after resting for 5 minutes.[13] Upon CR entry and completion, body weight, height, and body fat percentage were measured using a bioelectrical impedance analysis (BIA) scale [Tanita, TBF-310, Tokyo, Japan], while waist circumference was measured at the mid-point between the lowest ribs and the iliac crest. MetS was defined using the standard American Heart Association criteria.[4] Cardiorespiratory fitness (CRF) was measured at CR entry by peak oxygen consumption (VO_{2peak}) using an electronic/motorized treadmill test. VO_{2peak} was expressed as estimated metabolic equivalents (METs), and rating of perceived exertion was at peak. CRF was not measured at CR completion.

The current investigation was approved by and followed the recommendations of the Institutional Review Board of the University of Michigan Medical School (IRBMED) and was in accordance with the ethical standards as established by the 1964 Declaration of Helsinki and its later amendments.

Outcome

The primary outcome was the change in cardiometabolic risk factors from baseline to the completion of CR, as well as the difference of change in individuals with MetS compared to those without MetS.

Statistical Analysis

We compared baseline clinical and sociodemographic characteristics by MetS status using Wilcoxon rank-sum tests and Chi-square tests. Non-parametric Wilcoxon tests were used, not assuming normal distribution of continuous variables. The change in cardiometabolic parameters between baseline and completion of CR was assessed using non-parametric paired tests, or Wilcoxon signed-rank tests, as the same patients at baseline and at the end of CR were not independent. Patients with missing data for a specific measure, either at baseline or at the end of CR, were excluded when computing the statistics of the measure. To evaluate changes in cardiometabolic risk factors and measures of psychosocial health and cardiopulmonary fitness by MetS status, we conducted 17 difference-in-differences regression models, one for each measure, adjusting for age, sex, education, employment status, and indication for referral to CR. Patients who did not have MetS at baseline served as the reference group, as we hypothesized more improvement might be observed for patients having MetS at baseline. In difference-in-difference modeling, patients with missing data either at baseline or at the end of CR were excluded from modeling. An a-priori 2-tailed alpha of <0.05 was used to indicate statistical significance. All analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC).

Results

Our final analytic sample (n = 1984) had a mean age of 63.4 years of age in those with and without the MetS; 74.9% were male and 82.6% were White (Table 1). Overall, 1070 individuals (53.9%) met the criteria for MetS. Those with MetS were more likely to be female ($P = 0.001$), had lower educational attainment ($P < 0.0001$), and were less likely

Table 1 Comparison of Baseline Sociodemographic and Clinical Characteristics of Participants, by Metabolic Syndrome Status

Variable	Total, N = 1984[a]	Metabolic Syndrome, n = 1070 (53.9%)	No Metabolic Syndrome, n = 914 (46.1%)	Effect Size	*P*[b]
Age, years (mean ± SD)	63.4 ± 11.3	63.2 ± 10.7	63.6 ± 11.9	0.035	0.58
Males, n (%)	1486 (74.9)	770 (72.0)	716 (78.3)	0.146	0.001
White race/ethnicity, n (%)	1624 (82.6)	873 (82.1)	751 (83.2)	0.029	0.54
Married, n (%)	1433 (73.3)	759 (72.1)	674 (74.7)	0.059	0.19
Educational attainment, n (%)					
High school, some high school	253 (13.1)	158 (15.0)	95 (10.9)	0.122	< 0.0001
Associate's degree, some college	608 (31.5)	383 (36.2)	225 (25.8)	0.226	
Bachelor's degree or higher	360 (18.7)	177 (16.8)	183 (21.0)	0.107	
Post-graduate, professional degree	606 (31.4)	275 (26.0)	331 (38.0)	0.259	
Other	102 (5.3)	64 (6.1)	38 (4.4)	0.076	
Employment status, n (%)					
Active	831 (41.9)	417 (39.0)	414 (45.3)	0.128	0.0003
Retired	832 (41.9)	472 (44.1)	360 (39.4)	0.095	
Unemployed	70 (3.5)	41 (3.8)	29 (3.2)	0.033	
Medically disabled	116 (5.8)	79 (7.4)	37 (4.1)	0.142	
Unknown	135 (6.8)	61 (5.7)	74 (8.1)	0.095	
Indication for referral to cardiac rehab program, n (%)					
MI	516 (26.0)	255 (23.8)	261 (28.6)	0.109	0.003
MI/PCI	355 (17.9)	186 (17.4)	169 (18.5)	0.029	
PCI/stent	673 (33.9)	376 (35.1)	297 (32.5)	0.055	
CABG	345 (17.4)	186 (17.4)	159 (17.4)	0.000	
Stable angina	95 (4.8)	67 (6.3)	28 (3.1)	0.152	
Body composition, mean ± SD					
Weight, lbs	195.4 ± 43.7	210.4 ± 42.7	177.9 ± 38.0	0.804	< 0.0001
Body mass index, kg/m^2	29.8 ± 6.0	32.1 ± 5.8	27.1 ± 5.0	0.923	< 0.0001
Body fat percentage	31.3 ± 9.4	34.8 ± 8.9	27.0 ± 8.1	0.917	< 0.0001
Metabolic syndrome components, mean ± SD					
Waist circumference, in	40.9 ± 5.9	43.5 ± 5.4	37.8 ± 4.8	1.116	< 0.0001
HDL-C, mg/dL	42.6 ± 12.6	38.3 ± 9.6	47.9 ± 13.8	0.808	< 0.0001
Triglycerides, mg/dL	127.2 ± 73.2	152.7 ± 82.2	96.6 ± 44.5	0.849	< 0.0001
Fasting glucose, mg/dL	112.6 ± 36.8	124.3 ± 42.1	98.3 ± 21.6	0.777	< 0.0001
Systolic BP, mm Hg	117.2 ± 17.3	119.3 ± 17.3	114.7 ± 17.0	0.268	< 0.0001
Diastolic BP, mm Hg	65.7 ± 9.9	66.4 ± 9.8	64.9 ± 10.0	0.152	0.0004

Cardiometabolic risk factors, n (%)					
Type 1 diabetes	54 (2.7)	35 (3.3)	19 (2.1)	0.074	0.10
Type 2 diabetes	617 (31.1)	516 (48.2)	101 (11.1)	0.889	< 0.0001
Hyperlipidemia[c]	1852 (93.4)	1025 (95.8)	827 (90.5)	0.211	< 0.0001
Low HDL-C[d]	616 (31.1)	474 (44.3)	142 (15.5)	0.663	< 0.0001
Hypertension[e]	1434 (72.3)	935 (87.4)	499 (54.6)	0.775	< 0.0001
Physical inactivity[f]	310 (15.6)	179 (16.7)	131 (14.3)	0.066	0.14
Current smoking	106 (5.6)	63 (6.2)	43 (5.0)	0.052	0.29
Obesity	810 (40.8)	628 (58.7)	182 (19.9)	0.866	< 0.0001
Comorbidities, n (%)					
Stroke	19 (1.0)	11 (1.0)	8 (0.9)	0.010	0.819
Heart failure	27 (1.4)	13 (1.2)	14 (1.5)	0.026	0.565
Cardiac pacemaker or ICD	127 (6.4)	66 (6.2)	61 (6.7)	0.020	0.647
COPD	568 (28.6)	334 (31.2)	234 (25.6)	0.124	0.006
Peripheral vascular disease	295 (14.9)	186 (17.4)	109 (11.9)	0.156	0.001
Atrial fibrillation/flutter	453 (22.8)	240 (22.4)	213 (23.3)	0.021	0.668
Other lipids (mg/dL), mean ± SD					
Total cholesterol	138.1 ± 36.9	137.9 ± 37.2	138.3 ± 36.6	0.011	0.55
LDL-C	70.3 ± 28.9	69.7 ± 29.0	71.1 ± 28.8	0.048	0.17
Non-HDL-C	95.5 ± 34.1	99.7 ± 34.6	90.5 ± 32.7	0.273	< 0.0001
Pharmacotherapy, n (%)					
Diabetes	534 (26.9)	463 (43.3)	71 (7.8)	0.892	< 0.0001
High Triglycerides	36 (1.8)	32 (3.0)	4 (0.4)	0.198	0.0003
Low HDL-C	33 (1.7)	28 (2.6)	5 (0.5)	0.166	< 0.0001
Hypertension	1825 (92.0)	1036 (96.8)	789 (86.3)	0.385	< 0.0001
Statin	1827 (92.1)	1008 (94.2)	819 (89.6)	0.169	0.0002
Psychosocial health, mean ± SD					
BSI-53 global severity index	51.7 ± 10.3	52.2 ± 10.6	51.1 ± 10.0	0.107	0.02
BSI-53 depression score	51.5 ± 9.4	51.8 ± 9.7	51.2 ± 9.0	0.064	0.64
BSI-53 anxiety score	49.5 ± 10.0	49.6 ± 10.2	49.4 ± 9.7	0.020	0.80
BSI-53 hostility score	49.6 ± 9.0	50.1 ± 9.1	49.0 ± 8.7	0.124	0.01
Cardiopulmonary fitness					
Estimated METs	8.3 ± 3.1	7.4 ± 2.7	9.4 ± 3.3	0.663	< 0.0001
RPE	15.8 ± 4.4	15.6 ± 2.2	16.1 ± 6.1	0.109	0.11

Notes: [a]Percentages for some variables reflect missing observations. [b]From Wilcoxon rank-sum tests and Chi-square tests. [c]Total cholesterol ≥ 240 mg/dL, LDL-C ≥ 160 mg/dL, or treatment for elevated cholesterol. [d]HDL-C < 35 mg/dL for males, < 40 mg/dL for females, or treatment for low HDL. [e]Systolic blood pressure ≥ 130 mmHg, diastolic blood pressure ≥ 80 mmHg, or treatment for hypertension. [f]Self-reported daily physical activity level of "sedentary".
Abbreviations: SD, standard deviation; MI, myocardial infarction; PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft; HDL-C, high-density lipoprotein cholesterol; ICD, implantable cardioverter defibrillator; COPD, chronic obstructive pulmonary disease; LDL, low-density lipoprotein; BSI, brief symptom inventory; METs, metabolic equivalents; RPE, rating of perceived exertion.

https://doi.org/10.2147/DMSO.S470120

to be actively employed ($P < 0.0003$). Those with MetS were more likely to have a past medical history of COPD ($P = 0.006$) and peripheral vascular disease ($P = 0.001$). At baseline, those with MetS had slightly greater psychological distress, as evident by higher scores on the psychosocial health indicator BSI-53, but both groups were average for age/gender.

The most common qualifying diagnosis was PCI (33.9%), followed by MI (26.0%). There was no difference in CR sessions attended [MetS n = 1063, mean 23.6 ± 11.6, no MetS n = 905, mean 22.9 ± 11.6, $P = 0.157$], which was 2 or 3 sessions per week over 3 months. At baseline, those with MetS were more likely to be on medication for diabetes (ES = 0.892, $P = <0.0001$) and hypertension (ES = 0.385, $P = <0.0001$). While 92% of the total sample were being treated with cholesterol-lowering statins medication, less than 2.0% of patients were being treated with drugs specific for triglycerides and high-density lipoprotein cholesterol (HDL-C) across both groups.

At completion of CR, statistically significant improvement was observed in most measures of body composition and cardiometabolic risk factors as well as psychosocial health (Table 2). The change in biometric and cardiometabolic risk factors following participation in CR, by MetS status and components, is summarized in Table 2. After adjustment, both groups lost a significant amount of weight; however, compared to those without MetS, those with MetS lost an average of 1.43 pounds more (95% CI: 0.56, 2.31, $P = 0.001$), corresponding to a 0.21-point larger drop in body mass index (95% CI: 0.03, 0.37, $P = 0.02$), and also experienced a modestly greater reduction in waist circumference (−0.31 in [95% CI: −0.54, −0.08, $P = 0.008$]). A significant decrease in systolic blood pressure occurred in MetS which did not occur in the non-MetS group (−2.38 mmHg ± 17.68, $P = 0.002$), a difference that was not significant after adjustment ($P = 0.08$). As anticipated, there was a greater reduction in triglycerides and fasting glucose in those with MetS. The difference of change after adjustment for triglycerides was −8.70 mg/dL (95% CI: 15.04, −2.37, $P = 0.007$), and glucose −5.48 mg/dL (95% CI: −10.44, −0.53, $P = 0.03$). Both groups had an approximate 2 mg/dL increase in HDL-C. The mean baseline LDL-C was about 70 mg/dL in each group (Table 1) reflecting the use of statins, and both groups achieved an average of 25% further reduction in LDL-C. There was improvement in each of the variables of psychological distress in those with and without MetS with a greater improvement on adjusted difference in depression in those without MetS ($P = 0.03$).

Discussion

In this observational study, we found that participation in CR was associated with improved cardiometabolic risk profile, including reductions in systolic BP, weight, body fatness, lipids, and components of the MetS, as well as improved psychosocial health. Overall, compared to patients without MetS, those with MetS experienced a similar or greater improvement in cardiometabolic health.

Our findings are in line with evidence that CR improves clinical outcomes broadly[3] and MetS specifically.[7] However, other studies have found smaller associations of CR with improvement in metabolic parameters among those with DM,[9,10] which is not consistent with the results we found for MetS. It is not surprising that education and monitoring during CR would result in greater improvement in modifiable CHD risk factors such as triglycerides, waist circumference, weight, and blood pressure. In a study surveying patients' awareness of CVD risk factors at CR entry, the results showed that many patients are not aware of their risk factors and may even underestimate the significant risk factors such as a sedentary lifestyle, cigarette smoking and DM have on CVD.[14] These findings further support the use of CR programs, with targeted educational components, for improvement in cardiometabolic health, including each of the MetS criteria.

Differences in patient population, study design, skills of CR staff, and the specific CR intervention may also explain these discrepancies.[15] Furthermore, although MetS and DM often share a similar underlying pathology, it is possible that those with MetS may respond differently to CR than those with DM. In one study that specifically examined CHD patients with MetS, a 6-month CR program improved body composition, metabolic health, inflammation, and cardiopulmonary fitness.[16] However, that study only included patients with CABG and did not compare those with and without MetS.

The reduction in recurrent CV events and death following CR is well established. To what degree the positive benefits have long-term value in persons with and without MetS remains to be seen.[17] Given the increasing burden of cardiometabolic diseases, the prevalence of MetS in CHD, and the lack of long-term benefit of CR-like tailored programs

Table 2 Comparison of Changes in Cardiometabolic Risk Factors and Cardiopulmonary Fitness Outcomes Following Participation in Cardiac Rehabilitation, by Metabolic Syndrome Status

Variable	Metabolic Syndrome, N = 1070 (53.9%)			No Metabolic Syndrome, N = 914 (46.1%)			Difference of Change[c] (95% CI)			
	n[a]	Change from Baseline[b] (mean ± SD)	*P*	n[a]	Change from Baseline[b] (mean ± SD)	*P*	Unadjusted	*P*	Adjusted[d]	*P*
Body composition										
Weight, lbs	716	−4.68 ± 8.68	< 0.0001	636	−3.58 ± 7.37	< 0.0001	−1.10 (−1.96, −0.24)	0.01	−1.43 (−2.31, −0.56)	0.001
Body mass index, kg/m^2	714	−0.74 ± 1.82	< 0.0001	635	−0.56 ± 1.43	< 0.0001	−0.18 (−0.35, −0.01)	0.04	−0.21 (−0.37, −0.03)	0.02
Body fat percentage	619	−0.82 ± 3.23	< 0.0001	553	−0.57 ± 2.28	< 0.0001	−0.24 (−0.56, 0.07)	0.13	−0.31 (−0.63, 0.01)	0.06
Metabolic syndrome components										
Waist circumference, in	628	−0.81 ± 1.99	< 0.0001	545	−0.57 ± 1.94	< 0.0001	−0.24 (−0.46, −0.01)	0.04	−0.31 (−0.54, −0.08)	0.008
HDL-C, mg/dL	578	2.14 ± 6.73	< 0.0001	487	2.68 ± 8.15	< 0.0001	−0.54 (−1.45, 0.37)	0.24	−0.20 (−1.13, 0.73)	0.67
Triglycerides, mg/dL	578	−14.41 ± 61.05	< 0.0001	487	−5.09 ± 43.63	0.0001	−9.32 (−15.62, −3.02)	0.004	−8.70 (−15.04, −2.37)	0.007
Fasting glucose, mg/dL	375	−3.78 ± 37.03	0.001	167	1.74 ± 20.03	0.42	−5.52 (−10.33, −0.70)	0.02	−5.48 (−10.44, −0.53)	0.03
Systolic BP, mm Hg	715	−2.38 ± 17.68	0.002	630	−0.37 ± 16.49	0.70	−2.01 (−3.83, −0.18)	0.03	−1.68 (−3.55, 0.18)	0.08
Diastolic BP, mm Hg	715	−1.11 ± 10.59	0.008	628	−0.98 ± 10.27	0.05	−0.13 (−1.25, 0.99)	0.82	−0.26 (−1.41, 0.89)	0.66
Other lipids, mg/dL										
Total cholesterol	578	−0.08 ± 31.97	0.62	487	−1.20 ± 28.59	0.84	1.12 (−2.51, 4.76)	0.54	0.94 (−2.81, 4.69)	0.62
LDL-C	577	−19.59 ± 29.06	< 0.0001	486	−16.97 ± 28.85	< 0.0001	−2.62 (−6.11, 0.87)	0.14	−1.50 (−5.06, 2.05)	0.41
Non-HDL-C	578	−2.21 ± 30.33	0.11	487	−3.82 ± 26.54	0.002	1.61 (−1.81, 5.02)	0.36	1.08 (−2.43, 4.60)	0.55
Psychosocial health, mean ± SD										
BSI-53 global severity index	654	−3.66 ± 7.64	< 0.0001	572	−4.50 ± 7.76	< 0.0001	0.84 (−0.02, 1.71)	0.06	0.82 (−0.06, 1.71)	0.07
BSI-53 depression score	654	−1.67 ± 7.75	< 0.0001	572	−2.51 ± 7.14	< 0.0001	0.84 (0.00, 1.67)	0.05	0.92 (0.08, 1.76)	0.03
BSI-53 anxiety score	654	−3.32 ± 8.66	< 0.0001	572	−3.99 ± 8.59	< 0.0001	0.67 (−0.30, 1.63)	0.18	0.60 (−0.37, 1.57)	0.23
BSI-53 hostility score	654	−2.79 ± 8.00	< 0.0001	572	−2.26 ± 7.99	< 0.0001	−0.54 (−1.43, 0.36)	0.24	−0.39 (−1.32, 0.54)	0.41
Cardiopulmonary fitness										
RPE	485	−3.02 ± 3.04	< 0.0001	447	−3.53 ± 6.77	< 0.0001	0.51 (−0.17, 1.19)	0.14	0.34 (−0.26, 0.93)	0.27

Notes: [a]Number of patients with data at both baseline and end of program. [b]From Wilcoxon signed-rank tests. [c]From difference-in-differences regression models specifying robust estimates of variance. Patients without metabolic syndrome are treated as the reference. [d]Derived from difference-in-differences models adjusted for age, sex, education, employment status, and indication for referral to cardiac rehab.

Abbreviations: SD, standard deviation; CI, confidence interval; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; BSI, brief symptom inventory; METs, metabolic equivalents; RPE, rating of perceived exertion.

https://doi.org/10.2147/DMSO.S470120 DovePress

focused on promoting metabolic fitness, longer-duration chronic disease management than CR may be necessary to sustain the benefits.[18]

Our study has important strengths. We collected detailed cardiometabolic data both at baseline and at the completion of CR, allowing us to assess prospective changes in these variables. These data were collected as part of a comprehensive and ongoing preventive cardiology research database encompassing a range of CV risk factors and secondary prevention programs for individuals with established CVD. In addition, the data collection was conducted by trained staff using standardized protocols, minimizing reliance on patient recall and enhancing data accuracy.

Several limitations should also be considered. The study utilized medical records to identify relevant data, some of which were not originally collected for research purposes. As a result, the number of patients with sufficient data to specify MetS at CR exit is notably smaller compared to CR entry. Consequently, this reduced patient group may not be representative of the entire study cohort. Furthermore, we cannot rule out residual confounding, particularly due to unmeasured variables including fasting insulin, and inflammatory markers such as high sensitivity c-reactive protein. Finally, our sample consisted of predominantly very well-educated White patients at a major academic medical center; therefore, generalizability may be limited to populations with similar sociodemographic and cardiometabolic characteristics.

Conclusion

In conclusion, this study provides evidence to support the use of CR as a means to promote cardiometabolic health among patients with CHD. Compared to people without MetS, those with MetS experienced a comparable or greater benefit from CR, particularly with respect to improvements in MetS components. CR should be recommended for all eligible patients with CHD, including those with MetS.

Disclosure

The authors report no conflicts of interest in this work.

References

1. Alberti KGMM, Eckel RH, Grundy SM. et al. Harmonizing the Metabolic Syndrome. *Circulation*. 2009;120(16):1640–1645. doi:10.1161/CIRCULATIONAHA.109.192644
2. Vassallo P, Driver SL, Stone NJ. Metabolic Syndrome: an Evolving Clinical Construct. *Prog Cardiovasc Dis*. 2016;59(2):172–177. doi:10.1016/j.pcad.2016.07.012
3. Taylor RS, Dalal HM, McDonagh STJ. The role of cardiac rehabilitation in improving cardiovascular outcomes. *Nat Rev Cardiol*. 2022;19(3):180–194. doi:10.1038/s41569-021-00611-7
4. Grundy SM, Brewer Jr HB, Cleeman JI, Smith Jr SC, Lenfant C. Definition of metabolic syndrome: report of the National Heart, Lung, and Blood Institute/American Heart Association conference on scientific issues related to definition. *Circulation*. 2004;109(3):433–438. doi:10.1161/01.CIR.0000111245.75752.C6
5. Eckel RH, Grundy SM, Zimmet PZ. The metabolic syndrome. *Lancet*. 2005;365(9468):1415–1428. doi:10.1016/S0140-6736(05)66378-7
6. Einarson TR, Acs A, Ludwig C, Panton UH. Prevalence of cardiovascular disease in type 2 diabetes: a systematic literature review of scientific evidence from across the world in 2007-2017. *Cardiovasc Diabetol*. 2018;17(1):83. doi:10.1186/s12933-018-0728-6
7. Sadeghi M, Salehi-Abargouei A, Kasaei Z, Sajjadieh-Khajooie H, Heidari R, Roohafza H. Effect of cardiac rehabilitation on metabolic syndrome and its components: a systematic review and meta-analysis. *J Res Med Sci*. 2016;21(1):18. doi:10.4103/1735-1995.178757
8. Bianchi S, Maloberti A, Peretti A, et al. Determinants of Functional Improvement After Cardiac Rehabilitation in Acute Coronary Syndrome. *High Blood Press Cardiovasc Prev*. 2021;28(6):579–587. doi:10.1007/s40292-021-00473-7
9. Khadanga S, Savage PD, Ades PA. Insulin Resistance and Diabetes Mellitus in Contemporary Cardiac Rehabilitation. *J Cardiopulm Rehabil Prev*. 2016;36(5):331–338. doi:10.1097/HCR.0000000000000187
10. Laddu DR, Ozemek C, Hauer TL, et al. Cardiometabolic responses to cardiac rehabilitation in people with and without diabetes. *Int J Cardiol*. 2020;301:156–162. doi:10.1016/j.ijcard.2019.11.134
11. Brandt EJ, Garfein J, Pai CW, et al. Identifying Factors for Low-Risk Participation in Alternative Cardiac Rehabilitation Models for Patients with Coronary Heart Disease Using MI'S SCOREPAD. *Cardiovasc Ther*. 2023;2023:7230325. doi:10.1155/2023/7230325
12. Kolman L, Shin NM, Krishnan SM, et al. Psychological distress in cardiac rehabilitation participants. *J Cardiopulm Rehabil Prev*. 2011;31(2):81–86. doi:10.1097/HCR.0b013e3181f688e1
13. Muntner P, Shimbo D, Carey RM, et al. Measurement of Blood Pressure in Humans: a Scientific Statement From the American Heart Association. *Hypertension*. 2019;73(5):e35–e66.
14. Maloberti A, Monticelli M, Bassi I, Riccobono S, Giannattasio C. Low Awareness of Cardiovascular Risk Factor Among Patients Admitted in Cardiac Rehabilitation: new Data for Further Implementation of Cardiovascular Rehabilitation Program. *High Blood Press Cardiovasc Prev*. 2021;28(3):253–254. doi:10.1007/s40292-021-00451-z

15. Walden P, Jiang Q, Jackson EA, Oral EA, Weintraub MS, Rubenfire M. Assessing the incremental benefit of an extended duration lifestyle intervention for the components of the metabolic syndrome. *Diabetes Metab Syndr Obes*. 2016;9:177–184. doi:10.2147/DMSO.S94772
16. Onishi T, Shimada K, Sunayama S, et al. Effects of cardiac rehabilitation in patients with metabolic syndrome after coronary artery bypass grafting. *J Cardiol*. 2009;53(3):381–387. doi:10.1016/j.jjcc.2009.01.004
17. Joseph MS, Konerman MA, Zhang M, et al. Long-term outcomes following completion of a structured nutrition and exercise lifestyle intervention program for patients with metabolic syndrome. *Diabetes Metab Syndr Obes*. 2018;11:753–759. doi:10.2147/DMSO.S175858
18. Hamm LF, Kavanagh T, Campbell RB, et al. Timeline for peak improvements during 52 weeks of outpatient cardiac rehabilitation. *J Cardiopulm Rehabil*. 2004;24(6):374–80;quiz381–2. doi:10.1097/00008483-200411000-00002

Diabetes, Metabolic Syndrome and Obesity Dovepress

Publish your work in this journal

Diabetes, Metabolic Syndrome and Obesity is an international, peer-reviewed open-access journal committed to the rapid publication of the latest laboratory and clinical findings in the fields of diabetes, metabolic syndrome and obesity research. Original research, review, case reports, hypothesis formation, expert opinion and commentaries are all considered for publication. The manuscript management system is completely online and includes a very quick and fair peer-review system, which is all easy to use. Visit http://www.dovepress.com/testimonials.php to read real quotes from published authors.

Submit your manuscript here: https://www.dovepress.com/diabetes-metabolic-syndrome-and-obesity-journal