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Cardiometabolic responses to cardiac rehabilitation in people with and without diabetes

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Abstract

Background: Type 2 diabetes and cardiometabolic comorbidities manifesting as the metabolic syndrome (MetS) are highly prevalent in coronary heart disease (CHD) patients attending cardiac rehabilitation (CR). The study aimed to determine the prevalence of cardiometabolic derangements and MetS, and compare post-CR clinical responses in a large cohort of CHD patients with and without diabetes.

Methods: Analyses were conducted on 3953 CHD patients [age: 61.1 ± 10.5 years; 741 (18.7%) with diabetes] that completed a representative 12-week CR program. A propensity model was used to match patients with diabetes ($n = 731$) to those without diabetes ($n = 731$) on baseline and clinical characteristics.

Results: Diabetic patients experienced smaller improvements in metabolic parameters after completing CR, including abdominal obesity, and lipid profiles (all $P < .002$), compared to non-diabetic patients. For both groups, there were similar improvement rates in peak metabolic equivalents ([METs]; $P < .001$); however, peak METs remained lower at 12-weeks in patients with diabetes than without diabetes. At baseline, the combined prevalence of insulin resistance (IR) and diabetes was 57.3%, whereas IR was present in 48.2% of non-diabetic patients, of which rates

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Author contributions

DRL conceptualized the research question, performed the statistical data analysis and interpreted the results, and drafted, reviewed, and edited the manuscript. RA contributed to the conception and design of the study, and critically revised the manuscript for important intellectual content. CO, SBW, CRR, SA, TLH, TSC and LA contributed to the discussion and reviewed and provided critical revisions to the manuscript. TLH, LA, CRR, RA, and SA, contributed to data acquisition and curation and project administration, reviewed and revised the manuscript for important intellectual content. All authors agree with manuscript results and conclusions, approved the final version of the submitted and published manuscript. DRL is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for all aspects of the reliability and freedom from bias of the data presented and their discussed interpretation.

Declaration of competing interest

The authors report no relationships that could be construed as a conflict of interest. There are no relationships with industry to report, or relationships relevant to the contents of this paper to disclose by any of the author.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ijcard.2019.11.134>.

were reduced to 48.2% and 32.8% after CR, respectively. Accordingly, MetS prevalence decreased from 25.5% to 22.3% in diabetic versus 20.0% to 13.4% in non-diabetic patients (all $P < .004$).

Conclusions: Completing CR appears to provide comprehensive risk reduction in cardio-metabolic parameters associated with diabetes and MetS; however, CHD patients with diabetes may require additional and more aggressive attention towards all MetS criteria over the course of CR in order to prevent future cardiovascular events.

Keywords

Diabetes mellitus; Cardiac rehabilitation; Coronary artery disease; Metabolic syndrome; Cardiorespiratory fitness

1. Introduction

The global prevalence of type 2 diabetes (hereinafter referred to as diabetes) has nearly tripled in recent decades [1,2], reaching epidemic proportions in westernized countries including the US and Canada. Diabetes is recognized as a potent risk factor of cardiovascular disease (CVD) [3,4] such that individuals with diabetes have a 2–4-fold increase in their risk for myocardial infarction and stroke compared to their healthy counterparts [4,5]. Adults with diabetes who have suffered a major cardiovascular event have a poorer prognosis relative to adults without diabetes, including a higher risk of cardiovascular-related mortality [3,5,6]. Cardiometabolic comorbidities that collectively manifest as the metabolic syndrome ([MetS]; i.e., hypertension, dyslipidemia, impaired fasting glucose control, and abdominal obesity), are also highly prevalent among adults with coronary heart disease (CHD) and when aggregated with diabetes, may further amplify cardiovascular morbidity and mortality [7,8].

Exercise-based cardiac rehabilitation (CR) programs are recognized as a standard of care for patients with CVD, with prevention efforts focused on reducing or preventing secondary coronary events including death and cardiovascular-related morbidity, and improving risk factor profile, functional capacity and quality of life [9-11]. Despite the high and increasing prevalence of metabolic dysfunction in patients attending CR, there is limited evidence to suggest that patients with diabetes receive equivalent cardiometabolic benefit compared to patients without diabetes [3,12]. Further, given that the metabolic syndrome is closely related to diabetes, greater clinical attention is needed to understand the effects of CR on individual cardiometabolic derangements in the context of the MetS, which may provide some indication of targeted strategies for intervention in this multimorbid population. The objectives of this study were to: 1) determine the prevalence of cardiometabolic risk factors and MetS prior to CR participation in a large, well described cohort of CHD patients; and 2) compare post-CR clinical responses in those with and without diabetes. We hypothesized that patients with diabetes would have an overall higher burden of cardiometabolic risk factors and MetS at baseline, but would experience larger improvements in cardiometabolic profiles after completing CR.

2. Methods

2.1. Study population

A retrospective analysis was conducted on the data of patients who were referred to outpatient CR with the TotalCardiology™ Rehabilitation [TCR] program, in Calgary, Alberta, Canada between January 1996 and March 2016 [13]. The reason for referral, provincial health number (PHN), and baseline demographics were prospectively recorded for all referrals received, regardless of attendance. All patients were offered a multidisciplinary 12-week CR program, consistent with the Canadian Association of Cardiovascular Prevention and Rehabilitation guidelines [14]. Additional information on patient co-morbidities, coronary anatomy, vital statistics, therapeutic interventions, and adjudicated hospital readmissions, were obtained through a merge with the Alberta Provincial Project for Outcomes Assessment in Coronary Heart Disease (APPROACH) database [15]. Briefly, the APPROACH database captured all patients who underwent a cardiac catheterization and/or revascularization procedure in Alberta, Canada since 1995 [15]. The TCR and APPROACH databases were linked using PHNs, which are unique identifiers. This study was performed in accordance with the Helsinki Declaration and was approved by the Conjoint Health Ethics Review Board of the University of Calgary. All study participants gave written informed consent after receiving oral and written information about the study.

2.2. Patient selection

The APPROACH study design and eligibility criteria have been published elsewhere [13]. All patients included in the present analyses were over the age of 18 years and had completed the 12-week CR program, including a graded exercise test (GXT) and cardiometabolic risk profiles, at program start and completion. Patients were considered to have completed CR if they attended both their baseline and 12-week post-rehabilitation assessment [16]. Diabetic patients were considered those who reported a history of type 2 diabetes diagnosed or treated by a physician, or had diabetes indicated in their hospital record. Additional cross-checks were conducted in the APPROACH database, including extensive data audits in which records were merged with administrative databases, in order to verify diabetes diagnoses based on hospital coding in the Discharge Abstract Database [17].

2.3. Cardiac rehabilitation program

The 12-week multidisciplinary TCR program included one-hour supervised exercise sessions 2 times per week, with participants encouraged to engage in additional exercise sessions on their own. All the patients underwent a baseline assessment that included a complete cardiovascular examination, anthropometric measurements, a GXT following the Bruce or Modified Bruce protocol, and phlebotomy to assess lipid profile. Patients performed a symptom-limited maximal GXT to determine peak metabolic equivalents (METs) to assess CRF, to optimize patient safety, and to determine the exercise prescription. The peak MET value was calculated from treadmill speed and grade during the final stage of the exercise protocol using an established equation [18]. Each one-hour session was then supervised by a multidisciplinary team of physicians, exercise specialists, and registered

nurses, and included a 5 min warm-up, 20–60 min of steady state aerobic training (walking on an indoor track or using a treadmill, elliptical trainer, recumbent cross trainer, or cycle ergometer), performed at an intensity of 45–85% of the heart rate reserve (based on GXT test results), followed by a 5 min cool-down. Patients were provided a target heart rate and an associated MET level, and were further instructed on how to interpret the Borg 6–20 scale and exercise in the 12 to 14 range.

To supplement the exercise prescription, CR participants were offered individualized education, support with risk factor management, and access to a multidisciplinary team of healthcare providers. During the TCR program, patients with diabetes had capillary blood glucose levels measured by program nurses for the first 6 sessions, pre-exercise (2 h post-cibum); in patients with diabetes receiving insulin/secretagogues, additional monitoring occurred after exercise completion. Optimization of medical management was done by program physicians or by consulting primary care providers. Medication changes were made under physician direction. All the patients underwent a repeat assessment upon program completion (12-weeks) and were given instructions for ongoing lifestyle changes at home, including an exercise program and dietary advice.

2.4. Outcomes

Outcomes of interest included the MetS and cardiometabolic markers. Baseline and 12-week CR lipid profiles were analyzed within one month of starting and completing CR. Blood samples were collected under non-fasting conditions by trained phlebotomists and were analyzed by the Alberta Public Laboratories (Calgary, AB, Canada).

The presence of the MetS was determined using the recommended guidelines [19,20], defined as presence of at least three of the five following criteria: 1) waist circumference of >102 and >88 cm in White men and women, respectively [19]; and >90 and >80 cm in South Asian men and women, respectively [20]; 2) HDL cholesterol <1.03 and <1.29 mmol/L in men and women, respectively; 3) systolic blood pressure >130 or diastolic blood pressure >85 mm Hg, measured at rest with the patient in supine position; 4) triglycerides (TG) >1.7 mmol/L; and 5) insulin resistance using the ratio of TG to HDL ratio (TG/HDL) >1.2 mmol/L. Previous studies have found the TG/HDL ratio to be a valid indicator of insulin resistance (IR) [21] with a sensitivity and specificity comparable to criteria proposed by the Adult Treatment Panel III (ATP III) to diagnose MetS [19,22,23].

Additional cardiometabolic markers included LDL cholesterol (ideal LDL < 2.6 mmol/L by National Cholesterol Education Program [NCEP] ATP III goals [19]; <2.0 mmol/L by Canadian Cardiovascular Society [CCS] [24]), and peak METS performed before CR initiation (baseline) and at the end of the 12-week CR program. BMI was calculated from clinically measured weight (kg)/height (m)².

2.5. Study covariates

Baseline demographic and clinical characteristics were recorded in the TCR database. The APPROACH database linkage was used to obtain additional clinical covariates, including diagnosed hypertension, diabetes, chronic obstructive pulmonary disease (COPD), cerebrovascular disease (CEVD), congestive heart failure (HF), peripheral vascular disease

(PVD), and coronary interventions [percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG)], and results of coronary catheterization, including coronary anatomy (summarized by the Duke Jeopardy Score) [25]. Clinical covariates were captured only at the time of the initial catheterization; thus, the present analyses included only patients who were referred for CR within 1 year of their first catheterization to ensure that the covariate data reasonably reflected the state of the patient at CR, and thus eliminate potential bias introduced by any change in patient comorbidity status.

3. Statistical analysis

3.1. Propensity matching methods

Similar to our previously published methods [13], a nonparsimonious regression model was conducted to match and compare CHD patients with and without diabetes based on observed characteristics using logistic regression to produce a propensity score for CR treatment effect [13]. Propensity matching methods were applied to account for potential systematic differences in baseline characteristics between diabetic and nondiabetic patients that may arise when estimating the effect of CR on MetS and cardiometabolic comorbidities [26]. Propensity matched models included the following patient characteristics: 1) age; 2) sex; 3) ethnicity 4) baseline BMI; 5) coronary disease severity (defined by Duke Jeopardy score) [25]; 5) current or former smoker; 6) presence of malignancy; 7) dialysis; 8) HF; 9) COPD; 10) liver or gastrointestinal disease; 11) PVD; 12) CEVD; 13) prior CABG; 14) prior MI; 15) prior PCI; and, 16) prior ST/elevation MI. The model produced a propensity score for the probability of a CR treatment effect that was then used to match diabetics versus nondiabetic patients in a greedy 1-to-1 manner using PS matching with R-plug in within SPSS (Chicago, IL, USA). Balance in the matched groups was evaluated by ensuring that there was no more than a 10% difference present between the groups.

Baseline demographic and health characteristics were computed for the total sample and compared across diabetic and non-diabetic subgroups using chi (χ^2) or F-test statistics for categorical variables and independent (student's) *t*-test for continuous variables. Baseline and post (12-week) CR differences in each cardiometabolic comorbidity were compared using the paired-*t*-test and mean 12-week changes were computed as post-CR minus baseline values. A two-tailed value of $P < .05$ was defined as statistically significant. Statistical analyses were conducted using SPSS (Version 24.0; Chicago, IL, USA).

4. Results

A total of 22,978 patients were referred to CR between 1996 and 2016. Among these, 15,522 patients enrolled and started CR, of whom 11,850 (76.3%) had completed the 12-week CR program. Of these, 3953 patients [750 (19.0%) female; mean \pm SD age: 61.1 \pm 10.5 years] had no missing covariate data at baseline and 12-week assessments. Among this sample, 18.7% were identified as having diabetes, and propensity matching analysis yielded a final analytic sample size of 1462 patients (731 with diabetes and 731 without diabetes). Within propensity matched groups, men represented most of the study population (~80%). Patients with diabetes were more likely to be diagnosed with hypertension, hyperlipidemia, and a family history of CHD, and had more extensive CHD according to their Duke

Jeopardy scores (Table 1). Overall, patients included in the study appeared to have a lower prevalence of comorbidity burden and prior cardiovascular events, and had a less adverse cardiometabolic risk profile at baseline compared to patients who were excluded from the analyses due to non-compliance or who were non-responsive during the 12-week CR program (Supplemental Table 1).

At baseline, the MetS was prevalent in 25% of diabetic patients and 20% of non-diabetic patients (Fig. 1). IR was the most prevalent cardio-metabolic characteristic among diabetic (57.3%) and non-diabetic (48.2%) patients at the start of CR, followed by abdominal obesity, low HDL, high TG, and high BP. After completing CR, the percentage of patients with IR decreased by 16% in diabetic patients and 32% in non-diabetic patients. Further, a significant percentage of diabetic patients were no longer classified as having high TG (26%) or low HDL (6%), but 17% more diabetic patients experienced high BP (Supplemental Table 2, all $P_{pre-post} < .0001$), and the overall magnitude in prevalence change was considerably lower than “cure-rates” observed in nondiabetic patients (TG, 40%; HDL, 19%, P for between groups difference $< .03$). Accordingly, the proportion with MetS decreased by 3.3% (relative improvement of 13%) among patients with diabetes, and by 6.6% absolute (relative improvement of 33%) in non-diabetic patients (both groups $P_{pre-post} < .05$; P for between groups difference $< .01$).

Clinical profile of individual cardiometabolic measures among diabetic and non-diabetic patients are described in Table 2. Compared to non-diabetics, patients with diabetes had higher waist circumference, TG, IR levels, and lower HDL and initial peak METs, but also had lower LDL and diastolic BP (all $P < .05$). After CR completion, overall improvements in cardiometabolic comorbidities in diabetic patients were modest compared to those reported in non-diabetic patients (all P for between groups difference $> .002$). Specifically, IR reduced by 13% in diabetic patients and 21% non-diabetic patients. Though peak METs were significantly lower at baseline in diabetic patients, both diabetic and non-diabetic patients showed similar improvements in peak METs (both groups, 13% increase in peak METs). Both groups also demonstrated marked improvements in lipid profiles, particularly LDL-cholesterol, contributing to a greater proportion of diabetic and non-diabetic patients meeting ideal LDL thresholds established by CCS [24], and by the NCEP ATP III goals [19] (Fig. 2). However, the percentage of diabetic patients who attained lipid goals after completing CR was considerably lower for HDL and TG, compared to non-diabetic patients (P for between groups difference $< .024$). No significant improvement in systolic or diastolic BP was observed in either group after completing CR.

5. Discussion

In this large CR cohort, patients with and without diabetes demonstrated a reduction in the MetS prevalence, in addition to comprehensive cardiometabolic risk reduction after completing a 12-week CR program. However, overall improvements in the cardiometabolic risk profiles among patients with diabetes were smaller than improvements reported in patients without diabetes. Reductions in IR and increases in peak METs were among the most notable cardiometabolic benefits observed regardless of diabetes status, though, peak METs achieved after CR completion in diabetic patients remained lower than non-diabetic

counterparts. Improvements in lipid profiles translated to a greater percentage of patients meeting national lipid guidelines [19,24]; while, non-diabetic patients were more effective at meeting HDL and TG goals than diabetic patients.

Our findings represent the first systematic attempt to examine the changes in MetS, diabetes and other cardiometabolic risk factors during CR participation in a large population of CHD patients who completed CR. Our analyses adjusted for systematic differences in baseline patient characteristics, which may otherwise confound the observed CR “treatment” effect, by applying propensity matching methods to identify and uniquely balance diabetic and non-diabetic groups based on group similarities in various demographic, behavioral, and clinical covariates. As expected, the MetS burdened a higher proportion of diabetic (25.5%) than non-diabetic patients (20%). IR, which affected 57% diabetic patients and 48% non-diabetic patients, along with abdominal obesity, and low HDL levels were the three most common comorbidities that explained MetS prevalence in diabetic and non-diabetic groups. Contrary to our hypothesis, CR completion appeared less effective at improving MetS and metabolic derangements in diabetic patients than in nondiabetic patients. After CR completion, nearly 3.3% of diabetic patients no longer had MetS, an improvement rate of 13% that was clinically significant, albeit, modest compared to the 33% improvement rate noted in non-diabetic patients. The decrease in MetS prevalence observed in both groups was primarily explained by the change (% decrease) in the prevalence of patients who met the risk criteria for high TG (26%, 40%), IR (16%, 32%) and low HDL (6%, 19%) after 12-weeks.

It is important to highlight that the modest changes in individual MetS markers observed in both groups may have clinically meaningful health benefits. Both diabetic and non-diabetic patients, on average, experienced a 3% and 5% improvement (respectively) in HDL levels, which has been suggested to attenuate cardiac disease progression by 2%–3% [27]. More substantial improvements occurred in TG levels, which may translate into reduced risk of secondary cardiovascular events [28]. CR had the greatest effect on LDL cholesterol levels (diabetic patients, 18% decrease; non-diabetic patients, 24% decrease), consistent with previous studies [12,29,30] and the lipid lowering goals of traditional CR [9]. The net benefit of CR on lipid profiles resulted in a greater percentage of patients achieving national NCEP ATP III and CCS guidelines [19,24]. Despite appreciable improvements in lipid profiles, these findings corroborate with other studies [3,12,29,30] suggesting the need for more tailored lipid management approaches during CR, especially those that target HDL and TG levels. Further, our study showed that the IR levels favorably changed in patients with and without diabetes by 13% and 21%, respectively, indicating that all patients benefited from the exercise training and lifestyle modifications facilitated by CR.

CRF, measured in this study by peak METs, is considered to be one of the most important clinical vital signs for cardiovascular health [31]. We have previously reported in our CR patient sample, that those with the lowest baseline peak MET level achieved greater improvements in CRF after CR completion; however, diabetes was a significant and negative determinant of CRF [32]. In the present study, diabetic patients experienced similar improvements in peak METS relative to non-diabetic patients (~1 MET), translating to a 13% increase over 12 weeks, despite diabetic patients having a lower CRF at baseline and after CR compared to non-diabetic patients at baseline (6.7 versus 7.2 peak METs at

baseline and 7.6 vs. 8.2 peak METs at 12 weeks). For reasons that remain unknown, the 13% peak MET gain was considerably smaller than fitness gains observed in previous studies (range 22%–38%) [3,12,30,33]; though, the smaller sample of diabetic patients included in earlier studies, in addition to differences in disease severity, prevalence of comorbidity, medication use, and volume/intensity of exercise training are likely factors explaining this discrepancy [30]. Nonetheless, the average improvement of 1 MET increase is clinically meaningful, as our group has previously shown that each 1 MET increase translates to a 13% reduction in mortality [34].

Interestingly, improvements in peak METs and other cardiometabolic risk factors occurred without any change in BMI. Given the negative impacts of body weight on endurance, which often parallels a greater cardiometabolic risk burden, it is possible that greater weight reduction may have facilitated larger improvements in peak METs [7]. These data further emphasize critical gaps in CR concerning weight reduction strategies [7,12,33], and warrant the need for greater research to examine the added value of comprehensive weight loss interventions in combination with standard exercise-based CR for patients with and without diabetes.

5.1. Strengths & limitations

The availability of multiple clinical characteristics, including medical history, and existing comorbidities in this large dataset evaluating the effects of CR in a diabetic population are clear strengths of this analysis. Though we acknowledge that women were underrepresented in this study, our findings are likely generalizable to other CR centers as they describe a patient population that closely mimics contemporary CR programs. However, this study was restricted to those who completed CR, and thus, results may not be generalized to patients who do not enroll and/or do not complete CR. As such, differences observed between patients with and without diabetes may be partly attributable to lower exercise attendance and lower adherence to the self-management behaviors during CR, which we were unable to measure in this study. Further, while we confirm that patients in our study were correctly identified as having T2DM, it is possible that patients with undiagnosed type 2 diabetes were misclassified as non-diabetic patients and thus, we cannot rule out potential bias of these findings. Additionally, direct assessment of IR using HbA1c data were not available for most patients, however, TG/HDL, an established surrogate of IR that has been used in prior CR studies [3,35] was used to estimate the change in glycemic control after completing CR. Nonetheless, we acknowledge that more research is needed to verify the utility of the TG/HDL as a reliable indicator of IR in patients who are taking lipid-altering medications (e.g., statins) [8]. Accordingly, details of medication use (e.g., antihypertensive, lipid-lowering or antihyperglycemic therapies) were unavailable for this analysis. It therefore remains unclear whether cardiometabolic improvements observed after CR completion were due to the exercise intervention alone or due to other CR components (e.g., medication adherence, dietary change, psychosocial treatment) or stringent adjunctive therapies. Lastly, this study lacked detailed information regarding the number of CR sessions attended, perceived exertion at peak exercise, and follow-up measures on CHD status, which may have provided additional insight regarding differences in baseline and 12-week clinical profiles observed in diabetic and non-diabetic patients in this population.

6. Conclusion

The present study demonstrated that the MetS, and particularly IR, were common among CHD patients with and without diabetes enrolled in a comprehensive CR program. Completion of CR was associated with reduced MetS prevalence and improvements in various cardio-metabolic derangements, however, improvements were generally modest among diabetic patients compared non-diabetic patients. Given the rising prevalence of MetS and diabetes seen across populations with CVD, improvement in the delivery of evidence-based CR practices, including more routine screening of the MetS prior to CR initiation will be necessary in order to optimally reduce risk of secondary CHD events and mortality. CHD patients with diabetes may benefit from additional more aggressive weight reduction strategies (i.e., behavioral weight loss therapy) to ideally address clinical shortcomings in IR, and better manage BP, which together may lead to a better clinical trajectory.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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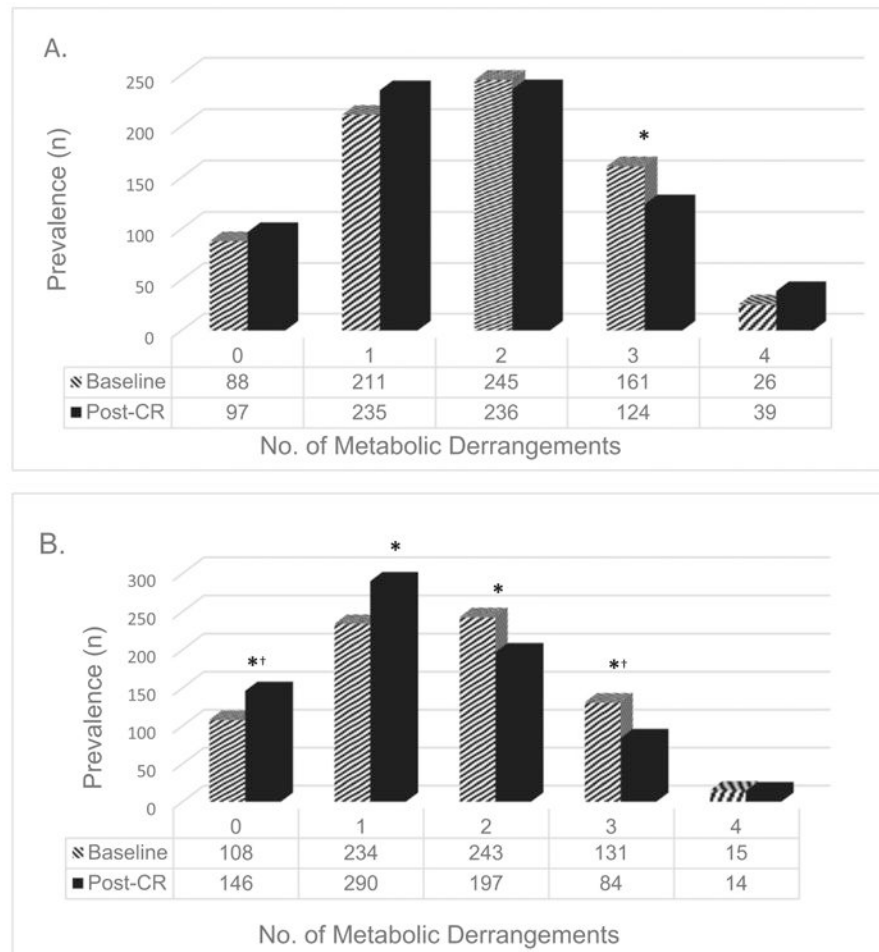


Fig. 1. Metabolic syndrome components at baseline and after cardiac rehabilitation completion in A) diabetic patients (n = 731) and B) non-diabetic patients (n = 731). CR, cardiac rehabilitation.

*Significant differences between baseline and 12-weeks (post-CR) metabolic markers; all $P < .004$ by paired sample t -test

†Significance at $P < .0001$ by paired sample t -test.

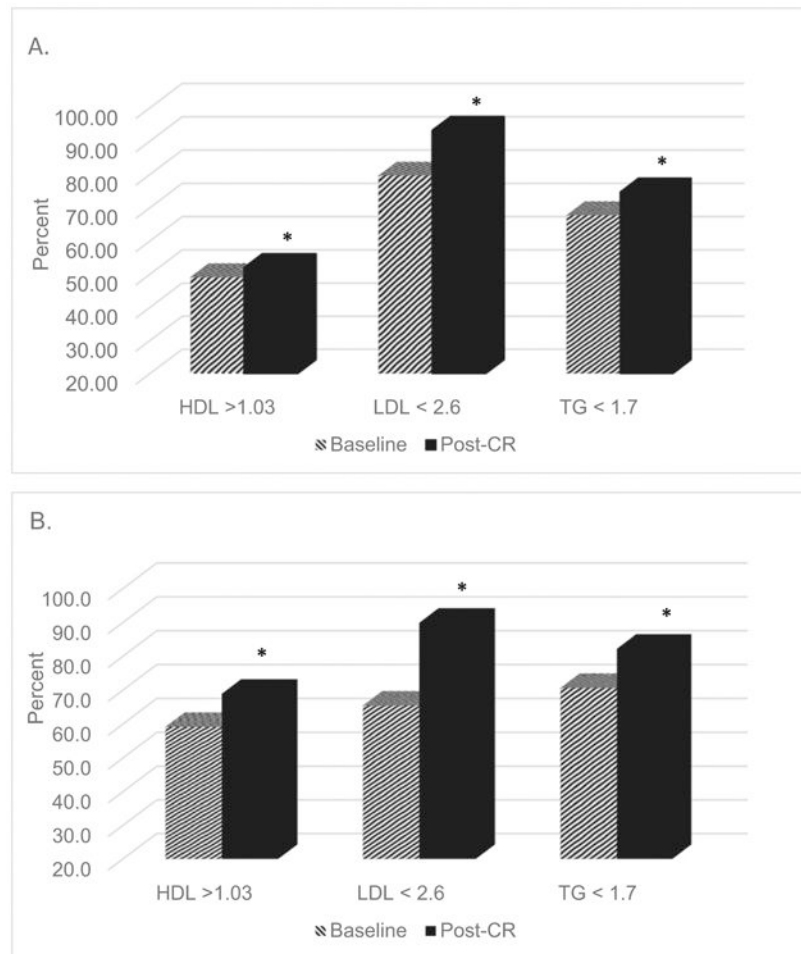


Fig. 2. Percent of patients meeting the NCET ATP III cholesterol guidelines at baseline and after cardiac rehabilitation completion in A) diabetic patients (n = 731) and B) non-diabetic patients (n = 731).

*Significant improvement in the percentage of patients meeting lipid guidelines from baseline to 12-week (post-CR) observed in diabetic and nondiabetic groups, respectively, all $P < .0001$, by paired sample t -test

Significant difference between percentages of diabetic versus non-diabetic patients meeting lipid guidelines after CR completion, all $P < .024$, by independent t -test.

Table 1.

Baseline Differences in Demographics and Clinical Characteristics in Cardiac Rehabilitation Patients with and without Type 2 Diabetes

	Entire Population* (n=3953)	Propensity Matched		P-value [†]
		Diabetic patients (n=731)	Non-Diabetic patients (n=731)	
Male, n (%)	3203 (81.0)	595 (81.4)	585 (80.0)	0.51
Age, mean, y ± SD	61.1 ± 10.5	62.6 ± 9.4	62.7 ± 10.7	0.94
Age categories, n (%)				
<40yrs	87 (2.0)	4 (0.5)	16 (2.2)	0.32
40 to <50yrs	482 (12.2)	58 (7.9)	80 (10.9)	0.01
50 to <60yrs	1259 (31.8)	223 (30.5)	187 (25.6)	0.05
60 to <70yrs	1310 (33.1)	285 (39.0)	259 (35.4)	0.04
70 to <80yrs	676 (17.1)	139 (19.0)	156 (21.3)	0.27
80yrs	139 (3.5)	22 (3.0)	33 (4.5)	0.16
Weight (kg)	84.9 ± 16.8	87.7 ± 17.3	87.9 ± 17.3	0.83
BMI categories (kg/m ²), n (%)				
<18.5	19 (0.5)	3 (0.4)	2 (0.3)	0.65
18.5-24.9	1047 (26.5)	150 (20.5)	145 (19.8)	0.75
25-29.9	1821 (46.1)	299 (40.9)	320 (43.8)	0.27
30-34.9	785 (19.9)	197 (26.9)	191 (26.1)	0.72
35-39.9	207 (5.2)	60 (8.2)	53 (7.3)	0.49
40	74 (1.9)	22 (3.0)	20 (2.7)	0.75
Ejection fraction	15.9 ± 34.8	16.2 ± 35.2	16.1 ± 35.1	0.95
Hypertension, n (%)	2407 (60.9)	582 (79.6)	440 (60.2)	0.0001
Hyperlipidemia, n (%)	2592 (65.6)	550 (75.2)	505 (69.1)	0.009
Congestive Heart Failure	233 (5.9)	63 (8.6)	66 (9.0)	0.43
COPD	401 (10.1)	91 (12.4)	94 (12.9)	0.81
Liver Disease	38 (1.0)	10 (1.4)	12 (1.6)	0.67
Liver/GI Disease	287 (7.3)	49 (6.7)	58 (7.9)	0.37
GI Disease	252 (6.4)	41 (5.6)	47 (6.4)	0.51
Malignancy	139 (3.5)	31 (4.2)	32 (4.4)	0.90
Peripheral vascular disease	159 (4.0)	22 (3.0)	19 (2.6)	0.64
Cerebrovascular disease	1332 (3.3)	25 (3.4)	22 (3.0)	0.66
Present Smoker	778 (19.7)	126 (17.2)	121 (16.6)	0.73
Former Smoker	1117 (28.3)	241 (33.0)	246 (33.7)	0.78
Renal Disease	54 (1.4)	17 (2.3)	13 (1.8)	0.46
Dialysis	10 (0.3)	2 (0.3)	3 (0.4)	0.65
Family History of Heart Disease	1395 (35.3)	267 (36.5)	227 (31.1)	0.03
Previous MI, n(%)	324 (8.2)	81 (11.1)	85 (11.6)	0.74
Prior PCI, n(%)	228 (5.8)	58 (7.9)	55 (7.5)	0.77
Prior CABG, n(%)	254 (6.4)	61 (8.3)	61 (8.3)	N/A

	Entire Population [*] (n=3953)	Propensity Matched		P-value [†]
		Diabetic patients (n=731)	Non-Diabetic patients (n=731)	
Indication for Catheterization, n(%)				
Stable angina	884 (22.4)	217 (29.7)	196 (26.8)	0.22
Myocardial infarction	2110 (53.4)	327 (44.7)	364 (49.8)	0.05
Unstable angina	517 (13.1)	95 (13.0)	92 (12.6)	0.81
Other	442 (11.2)	92 (12.6)	79 (10.8)	0.29
ST/Elevation MI, n (%)	1289 (32.6)	196 (26.8)	193 (26.4)	0.86
Duke Jeopardy Score n (%)				0.028
Normal	31 (2.1)	9 (1.2)	22 (3.0)	0.678
<50%	54 (3.7)	29 (4.0)	25 (3.4)	0.046
Low risk	665 (45.5)	313 (42.8)	352 (48.2)	0.003
High risk	560 (38.3)	308 (42.1)	252 (34.5)	0.606
Left main	151 (10.3)	72 (9.8)	79 (10.8)	N/A
missing	1 (0.1)	0 (0.0)	1 (0.1)	

Notes: Data are presented as mean (SD), or % as appropriate.

CABG, coronary artery bypass grafting; CR, cardiac rehabilitation; COPD, chronic obstructive pulmonary disease; MI, myocardial infarction; PCI, percutaneous coronary intervention

* Entire population based on unmatched patient population who completed Cardiac Rehabilitation.

† Overall difference across groups as determined by paired t-test or χ^2 test.

Table 2: Effect of Cardiac Rehabilitation on cardiometabolic risk factors in patients with and without Type 2 Diabetes

	Diabetic Patients (n=731)			Non-Diabetic patients (n=731)		
	Baseline	Post-CR*	Mean 12 week difference (%) †	Baseline	Post-CR ‡,§	Mean 12 week difference (%) †
BMI (kg/m ²)	29.1 ± 4.9	29.1 ± 4.9	0.03 ± 1.1 (0.1%)	28.9 ± 4.8	28.7 ± 4.9	-0.2 ± 1.1 (0.7%)
Waist Circumference (cm)	104.5 ± 13.3	104.1 ± 13.3	-0.5 ± 4.0 (-0.44)	102.9 ± 12.7	101.8 ± 12.7	-1.1 ± 3.9 (-1.1%)
Cardiorespiratory fitness (Peak METs)	6.7 ± 1.9	7.6 ± 2.0	0.9 ± 0.9 (13.0%)	7.2 ± 2.1	8.2 ± 2.1	1.0 ± 1.0 (13.2%)
Systolic BP (mmHg)	117.5 ± 18.6	118.7 ± 16.4	1.2 ± 17.5 (1.0%)	116.4 ± 18.1	116.7 ± 16.3	0.2 ± 17.0 (0.2%)
Diastolic BP (mmHg)	69.6 ± 9.8	69.9 ± 9.1	0.3 ± 10.0 (-0.45%)	71.1 ± 9.6	71.3 ± 9.2	0.1 ± 9.7 (0.18%)
HDL (mmol/L) ¶	1.06 ± 0.28	1.08 ± 0.27	0.03 ± 0.18 (1.9%)	1.14 ± 0.30	1.19 ± 0.31	0.06 ± 0.20 (5.3%)
LDL (mmol/L) ¶	1.91 ± 0.85	1.56 ± 0.67	-0.35 ± 0.82 (-18.3%)	2.28 ± 1.00	1.74 ± 0.70	-0.55 ± 0.95 (-23.7%)
TG (mmol/L) ¶	1.55 ± 0.78	1.39 ± 0.67	-0.16 ± 0.69 (-10.3%)	1.46 ± 0.72	1.22 ± 0.57	-0.24 ± 0.62 (-16.4%)
TG/HDL (mmol/L)	1.63 ± 1.06	1.41 ± 0.89	-0.22 ± 0.85 (-13.5%)	1.43 ± 0.92	1.12 ± 0.71	-0.30 ± 0.72 (-21.0%)

† mean 12week difference calculated as the difference of baseline and 12-week for each variable, and % change calculated relative to baseline (pre-CR), based on non-rounded values

* significant improvement in diabetic patients between baseline and post-CR metabolic markers (except SBP, DBP, and BMD), all *P* .002 by paired sample t-test

‡ significant improvement in non-diabetic patients between baseline and post-CR metabolic markers (except SBP, DBP), all *P* <.0001 by paired sample t-test

§ significant difference between diabetic and non-diabetic groups in all metabolic risk factors (except for SBP) at baseline, all *P* 0.03 *and* in all metabolic factors (except BMI) post CR, all *P* .02 as determined by independent t-test

¶ To convert HDL-C or LDL-C concentration to mg/dl, divide concentration in mmol/L by 0.02586.

¶ To convert triglyceride concentration to mg/dl, divide concentration in mmol/L by 0.01129.