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Clinical Research

Psychosocial and Cardiometabolic Health of Patients With Differing Body Mass Index Completing Cardiac Rehabilitation

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See editorial by Campbell et al., pages 684–687 of this issue.

ABSTRACT

Background: It remains unclear whether cardiac rehabilitation (CR) provides similar benefits to patients with varying levels of body mass index (BMI). We assessed the psychosocial and cardiometabolic health of patients with increased BMI who completed CR.

Methods: The records of 582 patients who completed a 3-month outpatient CR program were analyzed. On the basis of their BMI at baseline, patients were categorized as normal (18.5-24.9 kg/m^2), overweight (25.0-29.9 kg/m^2), obese (30.0-34.9 kg/m^2), or severely obese ($\geq$ 35.0 kg/m^2). Analysis of covariance was used to compare health-related quality of life (ie, Physical Component Summary [PCS] and Mental Component Summary scores), anxiety, depression, and cardiometabolic health indicators between BMI categories after CR.

Results: At baseline, patients with severe obesity, when compared with those with normal BMI, had lower PCS scores (39.7 $\pm$ 8.5 vs 44.4 $\pm$ 8.4,

RÉSUMÉ

Contexte : Il n'a pas encore été déterminé si les effets bénéfiques de la réadaptation cardiaque (RC) sont les mêmes quel que soit l'indice de masse corporelle (IMC). Nous avons évalué la santé psychosociale et cardiométabolique de patients ayant un IMC plus élevé qui avaient suivi une RC.

Méthodologie : Nous avons analysé les dossiers de 582 patients qui avaient suivi un programme de RC pendant trois mois en dehors de l'hôpital. Chaque patient a été classé, en fonction de son IMC, dans l'une ou l'autre des catégories suivantes : poids normal (de 18,5 à 24,9 kg/m^2), surpoids (de 25,0 à 29,9 kg/m^2), obésité (de 30,0 à 34,9 kg/m^2) ou obésité grave ($\geq$ 35,0 kg/m^2). L'analyse de la covariance a été utilisée pour comparer la qualité de vie liée à la santé (c.-à-d. les scores du sommaire de la composante physique [SCP] et du sommaire de la composante mentale) et les indicateurs de l'anxiété, de la

The proportion of people living with obesity in Canada, defined by a body mass index (BMI) of 30 kg/m^2 or higher, tripled between 1985 and 2011 (6.1% to 18.3%); a further increase is anticipated by 2019.[1] In particular, the percentage of people with more advanced obesity (ie, obesity class II: BMI 35.0-39.9 kg/m^2 and obesity class III: BMI $\geq$ 40.0 kg/m^2, hereafter collectively referred to as "severe obesity") has shown disproportionate growth.[1] The Canadian Health Measures Survey revealed that in 2015, 34.6% of the adult population were overweight, 17.2% were obese, and 9.5% were severely obese.[2] Greater BMI increases the risk of cardiovascular disease (CVD); the lifetime risk of developing CVD is more than 2.5 times higher in middle-aged adults with advanced obesity when compared with those with a normal BMI.[3]

Diminished psychosocial and cardiometabolic health are strong predictors of CVD and adversely affect recovery after major cardiovascular events.[4] Psychosocial health indicators, such as health-related quality of life (HR-QoL), anxiety, and depression,[5] frequently deteriorate with increasing BMI. Low HR-QoL is associated with a clustering of CVD risk factors, including diabetes, hypertension, and dyslipidemia.[6] Anxiety and depression predict higher CVD risk[7,8] because both are associated with inflammation, autonomic dysfunction, endothelial dysfunction, and platelet dysfunction,[9,10] as well as unfavorable behaviours (eg, unhealthy diets and smoking). In addition, overwhelming evidence reveals the association between greater body mass and insulin resistance, hypertension, and dyslipidemia,[11] all of which increase the risk of developing CVD.[12] Taken together, diminished psychosocial and

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$P < 0.001$), elevated levels of anxiety (7.0 ± 3.7 vs 4.8 ± 3.2, $P = 0.001$) and depression (5.5 ± 4.4 vs 3.4 ± 3.7, $P < 0.001$), higher glycated hemoglobin A1C (6.5 ± 1.1 vs 5.6 ± 0.7%, $P < 0.001$) and triglycerides (1.6 ± 0.5 vs 1.1 ± 0.4 mmol/L, $P < 0.001$), and lower high-density lipoprotein cholesterol (1.1 ± 0.3 vs 1.2 ± 0.4 mmol/L, $P = 0.006$). After CR, notwithstanding a greater percent weight reduction in obesity (−3.5% ± 6.9% vs +1.1% ± 7.0%, $P = 0.002$) and severe obesity (−6.5% ± 6.9% vs +1.1% ± 7.0%, $P < 0.001$), smaller improvements in PCS scores were seen in the obese (4.1 ± 7.4 vs 6.9 ± 7.6, $P = 0.011$) and severely obese (4.1 ± 7.6 vs 6.9 ± 7.6, $P = 0.039$) when compared with those with normal BMI.

Conclusions: Poorer psychosocial and cardiometabolic health at baseline coupled with smaller improvements in the PCS score suggest that patients with obesity and severe obesity will benefit from enhanced care in the CR setting.

dépression et de la santé cardiométabolique des patients des différentes catégories d'IMC après la RC.

Résultats : Au départ, les patients atteints d'obésité grave, comparativement à ceux ayant un IMC normal, présentaient un score du SCP moins élevé (39,7 ± 8,5 vs 44,4 ± 8,4, $p < 0,001$), des degrés élevés d'anxiété (7,0 ± 3,7 vs 4,8 ± 3,2, $p = 0,001$) et de dépression (5,5 ± 4,4 vs 3,4 ± 3,7, $p < 0,001$), un taux plus élevé d'hémoglobine glyquée A_{1C} (6,5 ± 1,1 vs 5,6 ± 0,7 %, $p < 0,001$) et de triglycérides (1,6 ± 0,5 vs 1,1 ± 0,4 mmol/l, $p < 0,001$) et un taux plus faible de cholestérol à lipoprotéines de haute densité (1,1 ± 0,3 vs 1,2 ± 0,4 mmol/l, $p = 0,006$). Après la RC, malgré une réduction de poids en pourcentage plus élevée dans les groupes des patients atteints d'obésité (-3,5 % ± 6,9 % vs +1,1 % ± 7,0 %, $p = 0,002$) et d'obésité grave (-6,5 % ± 6,9 % vs +1,1 % ± 7,0 %, $p < 0,001$), des améliorations moins marquées du score au SCP ont été observées chez les patients obèses (4,1 ± 7,4 vs 6,9 ± 7,6, $p = 0,011$) et gravement obèses (4,1 ± 7,6 vs 6,9 ± 7,6, $p = 0,039$) comparativement à ceux ayant un IMC normal.

Conclusions : Du fait de leur moins bonne santé psychosociale et cardiométabolique initiale conjuguée à des améliorations plus faibles du score au SCP, les patients atteints d'obésité ou d'obésité grave tireront profit de la prise en charge améliorée offerte dans le cadre d'une RC.

cardiometabolic health play an important role in the development and progression of CVD in individuals with greater body mass.

Cardiac rehabilitation (CR) consistently has been shown to improve HR-QoL,[13] anxiety,[14,15] depression,[15,16] and cardiometabolic health indicators.[13] Such programs afford significant opportunities to forestall the progression of CVD[8] and reduce mortality.[15] Contemporary CR programs have, however, remained largely unchanged in their style and structure[17] despite the evolving, more complicated patient profiles reflecting rising rates of overweight and obesity.[18] Patients with overweight and obesity comprise more than 80% of patients receiving CR;[18] they experience a higher incidence of recurrent, nonfatal cardiac events.[19]

The effects of CR on psychosocial and cardiometabolic health in patients who are overweight or obese remain unclear. Previous studies assessing the impact of CR on HR-QoL of patients with differing BMI have reported inconsistent findings: similar improvements in HR-QoL regardless of BMI[20] and improvements only in patients who are overweight but not those with normal BMI or obesity.[21] Likewise, studies have shown that CR programs improve fasting blood glucose in those of normal weight but not in patients with severe obesity,[18] suggesting that the effect of CR on cardiometabolic health indicators may be body-mass dependent. No studies have compared the changes in other psychosocial and cardiometabolic health indicators (eg, anxiety, depression, and glycated hemoglobin A1c [HbA1c]) among those with differing BMI after CR, leaving an important gap in the literature.

Given that patients who are overweight or obese now comprise the majority of the patient population receiving CR, it is important to assess the impact of CR among those with greater BMI. The purpose of this study was to determine whether CR would produce similar improvements in psychosocial and cardiometabolic health indicators in patients who are overweight or obese when compared with those with normal BMI. We hypothesized that patients with obesity and severe obesity would demonstrate similar changes in psychosocial and cardiometabolic health indicators.

Methods

Study design

We retrospectively analyzed longitudinal data acquired from patients with CVD who completed a 3-month outpatient CR program between 2011 and 2015 at a tertiary-care cardiovascular treatment centre. Body mass (kg) and height (cm) were measured at baseline, and BMI (kg/m^2) was calculated. Patients were subsequently categorized as normal BMI (18.5-24.9 kg/m^2), overweight (25.0-29.9 kg/m^2), obese (30.0-34.9 kg/m^2), or severely obese ($\geq$ 35.0 kg/m^2). A research assistant retrieved information regarding patients' age, sex, ethnicity, medical diagnosis, prescribed medication, total household income, type of CR program (ie, on-site, home-based, or brief), and referrals to additional CR services (ie, vocational counseling, nutritional counseling, stress management, medical appointment, social work counseling, and psychological counseling). Approval for the study was obtained from the Ottawa Health Sciences Network Research Ethics Board (protocol #: 20180675-01H).

CR program

Patients participated in 1 of 3 CR programs: on-site, home-based, or brief. All 3 CR programs included on-site coronary risk factor management consisting of a risk-factor modification consultation with a physiotherapist or registered nurse and, if required, referral to additional CR services. In addition to coronary risk management, the on-site CR program included supervised exercise training; the

home-based CR program included 10 weekly risk-factor management phone calls and exercise counseling specific to the home setting, and the brief CR program included an exercise prescription to be followed at home or elsewhere.

The on-site exercise program consisted of supervised exercise training sessions twice weekly for up to 3 months. Each exercise training session was 60 minutes in duration and followed conventional CR guidelines: (1) warm-up for 5 to 10 minutes; (2) aerobic conditioning for 20 to 40 minutes at moderate to vigorous intensity (40%-85% heart rate reserve); and (3) cool-down for 5 to 10 minutes of stretching and conditioning exercises.[22] A general prescription for the home-based exercise training was individualized by CR staff on the basis of a patient's health and his/her residential circumstances.

Outcome measures

Health-related quality of life. The Medical Outcomes Study Short Form-36 was administered at baseline and after the 3-month CR program to assess patients' satisfaction with their personal physical and mental well-being (ie, HR-QoL).[23] The Short Form-36 is a thoroughly validated, standardized, general health survey consisting of 36 questions.[23] It yields an 8-scale profile of functional health and well-being scores (physical functioning, role limitations due to physical health, role limitations due to emotional problems, energy, emotional well-being, social functioning, bodily pain, and general health), as well as psychometrically based Physical Component Summary (PCS) and Mental Component Summary (MCS) scores. The minimal clinically important difference (MCID) for the PCS and MCS has been suggested to be ≥ 5 points.[24]

Anxiety and depression. Anxiety and depression were assessed using the Hospital Anxiety and Depression Scale (HADS) at baseline and after the 3-month CR program. The HADS is a 14-item self-report scale that yields separate anxiety and depression scores (7 items each).[25] Each item is rated on a 4-point scale (0-3 points). Subscale scores range from 0 to 21, and scores above 7 are considered elevated.[25] With its established psychometric properties and de-emphasis of somatic symptoms, the HADS has been widely used within medical populations, including patients with cardiac disease. The MCID for the HADS scores is ≥ 1.7 points.[26]

Cardiometabolic health indicators. Cardiometabolic health indicators assessed in our study included the following: body mass, waist circumference, systolic blood pressure, diastolic blood pressure, HbA1c, fasting plasma glucose (FPG), total cholesterol, triglycerides (TG), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol. Body mass, waist circumference, resting systolic blood pressure, and diastolic blood pressure were measured using standardized procedures by CR professionals.[27] Glucose and lipid profiles were measured at a local accredited laboratory. We considered $\geq 5\%$ body mass reduction achieved during the course of the CR program as a clinically meaningful change.[28]

Statistical analysis. Baseline characteristics were compared among BMI categories using analysis of variance for continuous variables and chi-square analyses for categorical variables. Baseline and 3-month CR data were compared in each BMI category by paired t tests. Changes in psychosocial and cardiometabolic health indicators across BMI categories after CR were compared using analysis of covariance. Covariates included age, sex, ethnicity, income, type of CR, use of additional CR services, concomitant cardiac conditions, prescribed medication, and the baseline measure of dependent variables. When a significant difference was found, each group was compared with the normal BMI group using post hoc comparisons with Dunnett adjustment. For sensitivity analysis, we repeated the same analyses exclusively on patients who completed on-site CR.

Data normality was tested with the Kolmogorov-Smirnov test. MCS, anxiety, depression, HbA1c, FPG, total cholesterol, TG, LDL-C, and high-density lipoprotein cholesterol were transformed for normality. Because the transformed data showed consistent results with nontransformed data, outputs using the nontransformed data are reported. Data were analyzed using Minitab 18 Statistical Software (2010, Minitab, Inc, State College, PA). $P < 0.05$ was considered significant.

Results

Patient characteristics at baseline

Of the 591 patients who participated in CR, 7 with missing body mass measures and 2 with BMI < 18.5 kg/m^2 (ie, underweight) were excluded. Of the remaining 582 patients, 117 (20.1%) were classified as normal weight, 264 (45.4%) were classified as overweight, 126 (21.6%) were classified as obese, and 75 (12.9%) were classified as severely obese. Baseline patient characteristics are shown in Table 1. Baseline psychosocial and cardiometabolic health indicators are summarized in Table 2.

When compared with patients with normal BMI, patients with severe obesity were younger, had lower PCS scores, experienced greater anxiety and depression, and presented with more adverse cardiometabolic health indicators, such as higher HbA1c, FPG, and TG. The proportion of patients with depression (ie, HADS > 7 score) was higher in patients with severe obesity when compared with those with normal BMI. Patients with obesity presented with more adverse cardiometabolic health indicators, such as higher levels of HbA1c, FPG, and TG, when compared with those with normal BMI.

CR types and use of additional CR services

A significantly smaller proportion of patients with severe obesity participated in the brief CR program when compared with those with normal BMI (Table 1). There were no significant differences in the proportion of patients participating in on-site and home-based CR among BMI categories. There were no differences in the rates of referrals to additional CR services among BMI categories.

Changes in psychosocial health indicators

All BMI categories showed improvements in the PCS scores, MCS scores, and levels of anxiety and depression (all P

Table 1. Patient characteristics at CR baseline

	BMI			
	Normal (n = 117)	Overweight (n = 264)	Obese (n = 126)	Severely obese (n = 75)
Female, n (%)	38 (32.5)	60 (22.7)	26 (20.6)	26 (34.7)
Age (y)	65 (10)	**62 (9)**†	63 (9)	**61 (9)**†
Anthropometrics				
Height (cm)	169.7 (8.7)	171.6 (8.9)	170.9 (9.2)	168.1 (9.2)
Body mass (kg)	68.2 (8.4)	**80.6 (9.2)**‡	**92.9 (10.3)**‡	**113.6 (15.5)**‡
BMI (kg/m^2)	23.1 (1.2)	**27.5 (1.3)**‡	**31.9 (1.3)**‡	**40.0 (5.5)**‡
Waist circumference (cm)	82.0 (8.2)	**92.3 (7.4)**‡	**103.4 (7.2)**‡	**119.3 (10.3)**‡
Ethnicity				
Aboriginal	1 (0.9)	3 (1.1)	3 (2.4)	1 (1.3)
Asian	13 (11.1)	15 (5.7)	4 (3.2)	1 (1.3)
Black	0 (0)	2 (0.8)	2 (1.6)	0 (0)
Hispanic	1 (0.9)	1 (0.4)	0 (0)	1 (1.3)
White	99 (84.6)	237 (89.8)	113 (89.7)	70 (93.3)
Others	3 (2.6)	6 (2.3)	4 (3.2)	2 (2.7)
CR programs, n (%)				
On-site	71 (60.7)	160 (60.6)	91 (72.2)	56 (74.7)
Home-based	18 (15.4)	57 (21.6)	18 (14.3)	14 (18.7)
Brief	26 (22.2)	38 (14.4)	16 (12.7)	**2 (2.7)***
Total household income				
< 40,000	19 (16.2)	34 (12.9)	18 (14.3)	12 (16.0)
≥ 40,000 and < 70,000	30 (25.6)	67 (25.4)	37 (29.4)	21 (28.0)
≥ 70,000	34 (29.1)	109 (41.3)	42 (33.3)	29 (38.7)
Unknown	34 (29.1)	54 (20.5)	29 (23.0)	13 (17.3)
Comorbidities, n (%)				
Diabetes	13 (11.1)	40 (15.2)	33 (26.2)	**29 (38.7)**‡
Asthma	12 (10.3)	**12 (4.5)***	11 (8.7)	11 (14.7)
Emphysema	1 (0.9)	0 (0.0)	1 (0.8)	**4 (5.3)**‡
Cancer	14 (12.0)	28 (10.6)	18 (14.3)	8 (10.7)
Arthritis	22 (18.8)	47 (17.8)	27 (21.4)	**28 (37.3)**†
Addiction	3 (2.6)	6 (2.3)	3 (2.4)	3 (4.0)
Anemia	6 (5.1)	5 (1.9)	6 (4.8)	2 (2.7)
Chronic pain	30 (25.6)	**63 (23.9)***	40 (31.7)	**39 (52.0)**‡
Cardiovascular conditions, n (%)				
Angina	26 (22.2)	**93 (35.2)***	**50 (39.7)***	**23 (30.7)***
Coronary artery graft bypass surgery	33 (28.2)	64 (24.2)	37 (29.4)	16 (21.3)
Percutaneous coronary intervention	51 (43.6)	**160 (60.6)**†	64 (50.8)	34 (45.3)
Coronary heart disease	2 (1.7)	7 (2.7)	2 (1.6)	4 (5.3)
Congestive heart failure	5 (4.3)	22 (8.3)	8 (6.3)	7 (9.3)
Cardiomyopathy	2 (1.7)	5 (1.9)	2 (1.6)	1 (1.3)
Heart murmur	14 (12.0)	21 (8.0)	12 (9.5)	11 (14.7)
Carotid disease	4 (3.4)	4 (1.5)	4 (3.2)	2 (2.7)
Stroke	1 (0.9)	8 (3.0)	6 (4.8)	3 (4.0)
Transient ischemic attack	2 (1.7)	14 (5.3)	4 (3.2)	3 (4.0)
Medications, n (%)				
Antihypertensive agents	93 (79.5)	218 (82.6)	103 (81.7)	66 (88.0)
Cholesterol-lowering agents	91 (77.8)	236 (89.4)	112 (88.9)	63 (84.0)
Antidiabetic agents	6 (5.1)	35 (13.3)	24 (19.0)	**23 (30.7)**‡
Mood-control agents	4 (3.4)	19 (7.2)	16 (12.7)	8 (10.7)

BMI, body mass index; CR, cardiac rehabilitation.

Data are reported as mean (standard deviation) for continuous variables.

Comparisons were made against the normal BMI group with Dunnett adjustment. Bold fonts represent significant differences from the normal BMI group: *$P < 0.05$, †$P < 0.01$, and ‡$P < 0.001$.

Normal BMI: 18.5-24.9 kg/m^2; overweight: 25.0-29.9 kg/m^2; obese: 30.0-34.9 kg/m^2; severely obese: ≥ 35.0 kg/m^2.

< 0.05). Improvements in the PCS scores were significantly different among BMI categories ($P = 0.012$), whereas no between-group differences were seen for changes in MCS, anxiety, or depression after CR (Fig. 1). Post hoc analysis of the PCS scores revealed smaller gains in patients with obesity (4.1 ± 7.4 vs 6.9 ± 7.6, $P = 0.011$) and severe obesity (4.1 ± 7.6 vs 6.9 ± 7.6, $P = 0.039$) when compared with those with normal BMI. Our sensitivity analysis including only those who completed on-site CR showed consistent results ($P = 0.035$). Given the significant differences in improvements in the PCS scores, we explored the 8 subscales of functional health and well-being that comprise the PCS score. We found that CR improved subcategories comprising PCS regardless of BMI. However, improvements in "physical functioning" were significantly smaller in patients with obesity and severe obesity when compared with normal BMI (Fig. 2).

Changes in cardiometabolic health indicators

Changes in cardiometabolic health indicators are summarized in Figure 3. A significant between-group difference in the percent body mass reduction was observed after CR

Table 2. Psychosocial and cardiometabolic health indicators at CR baseline

	BMI			
	Normal (n = 117)	Overweight (n = 264)	Obese (n = 126)	Severely obese (n = 75)
Psychosocial health indicators				
PCS score (points)	44.3 (8.4)	43.4 (7.8)	41.6 (7.4)	**40.3 (8.5)**†
MCS score (points)	49.3 (9.3)	49.1 (9.9)	48.4 (10.6)	46.7 (11.1)
HADS anxiety score (points)	4.9 (3.2)	5.3 (3.1)	5.8 (3.5)	**6.7 (3.7)**‡
Elevated anxiety (score ≥ 7) n (%)	28 (23.9)	72 (27.3)	40 (31.7)	29 (38.7)
HADS depression score (points)	3.5 (3.7)	3.6 (3.8)	4.1 (4.5)	**5.6 (4.4)**‡
Elevated depression (score ≥ 7) n (%)	14 (12.0)	32 (12.1)	23 (18.3)	**22 (29.3)**†
Cardiometabolic health indicators				
Systolic blood pressure (mm Hg)	120 (17)	123 (16)	124 (18)	124 (19)
Diastolic blood pressure (mm Hg)	69 (10)	70 (9)	70 (10)	70 (11)
HbA1c (%)§	5.6 (0.7)	5.9 (0.8)	**6.0 (1.1)***	**6.5 (1.1)**‡
FPG (mmol/L)§	5.4 (0.8)	5.8 (1.6)	**6.1 (1.6)**†	**6.6 (1.8)**‡
Total cholesterol (mmol/L)§	3.5 (1.1)	3.6 (1.0)	3.6 (0.8)	3.7 (0.9)
TG (mmol/L)§	1.1 (0.4)	**1.4 (0.8)**†	**1.4 (0.7)**†	**1.6 (0.5)**‡
HDL-C (mmol/L)§	1.2 (0.4)	**1.2 (0.5)**†	**1.1 (0.3)***	**1.1 (0.3)**†
LDL-C (mmol/L)§	1.8 (0.9)	1.8 (0.7)	1.8 (0.6)	1.9 (0.7)

BMI, body mass index; CR, cardiac rehabilitation; FPG, fasting plasma glucose; HADS, Hospital Anxiety and Depression Scale; HbA1c, glycated hemoglobin A1C; HDL-C, high-density lipoprotein-cholesterol; LDL-C, low-density lipoprotein-cholesterol; MCS, Mental Component Summary; PCS, Physical Component Summary; TG, triglycerides.

Data are reported as mean (standard deviation) for continuous variables.

Comparisons were made against the normal BMI group with Dunnett adjustment. Bold fonts represent significant differences from the normal BMI group: *$P < 0.05$, †$P < 0.01$, and ‡$P < 0.001$.

Normal BMI: 18.5-24.9 kg/m^2; overweight: 25.0-29.9 kg/m^2; obese: 30.0-34.9 kg/m^2; severely obese: ≥ 35.0 kg/m^2.

§ n = 125 for women and n = 331 for men.

($P < 0.001$). Post hoc analysis revealed that patients with obesity (−3.3% ± 9.1% vs +0.3% ± 9.4%, $P = 0.002$) and severe obesity (−6.9% ± 9.2% vs +0.3% ± 9.4%, $P < 0.001$) experienced a significantly greater decrease in body mass when compared with those with normal BMI. Our sensitivity analysis showed consistent outcomes ($P < 0.001$). Cardiometabolic biomarker measures were available from 456 patients. There were no significant group differences in the changes in cardiometabolic health indicators.

Discussion

An improved understanding of how patients who are overweight or obese respond to CR could lead to the development of more enhanced, individualized care. This study compared the changes in psychosocial and cardiometabolic health indicators in patients with higher BMI after a CR program. The principal finding was that although CR is effective in improving various psychosocial and cardiometabolic health indicators, the gain in physical HR-QoL (ie, PCS score) was smaller in patients with obesity and severe obesity when compared with those with normal BMI. Of note, although the changes in the PCS scores reached the MCID in patients with normal BMI and those who were overweight, the improvements failed to reach the MCID (ie, ≥ 5 points[24]) in patients with obesity and severe obesity. The PCS score is a predictor of mortality and hospitalization in patients with CVD,[29] underscoring the importance of addressing physical HR-QoL among patients with obesity in CR. Our results also showed that patients with obesity entering a CR program, especially those with severe obesity, had diminished psychosocial and cardiometabolic health, suggesting a greater likelihood of an unfavourable prognosis and secondary cardiovascular events.[4]

Among those with severe obesity, the overall combination of lower PCS scores, greater anxiety and depression, and a greater proportion of patients with a significantly elevated HADS depression score (ie, ≥ 7) at baseline warrants careful consideration because poor psychosocial health can increase the risk of secondary events.[4] Diminished psychosocial health indicators are linked to a greater likelihood of adverse health behaviours,[30] including physical inactivity, poor diet, smoking, and problematic alcohol consumption, as well as increased cortisol concentrations and platelet activation via mechanisms involving excessive activation of the sympathetic nervous system.[7] Therefore, those with severe obesity are at higher risk of subsequent coronary artery atherosclerosis and transient endothelial dysfunction. The mechanisms contributing to the impaired psychosocial health among those with severe obesity may include an increased risk of medical complications, lowered self-esteem, and a greater likelihood of experiencing long-term body image dissatisfaction, prejudice, and discrimination.[31] Weight stigma, internalization of weight bias, and other psychological stressors are identified mediators of anxiety and depression.[11] CR programs addressing these root causes of impaired psychosocial health may benefit patients with obesity.

At baseline, cardiometabolic health indicators were relatively well controlled in all BMI categories. However, consistent with the findings of others,[18] patients with obesity and severe obesity experienced higher glucose and lipid concentrations when compared with those with a normal BMI. The presence of adverse cardiometabolic health indicators is known to increase the rate of unstable angina, recurrent

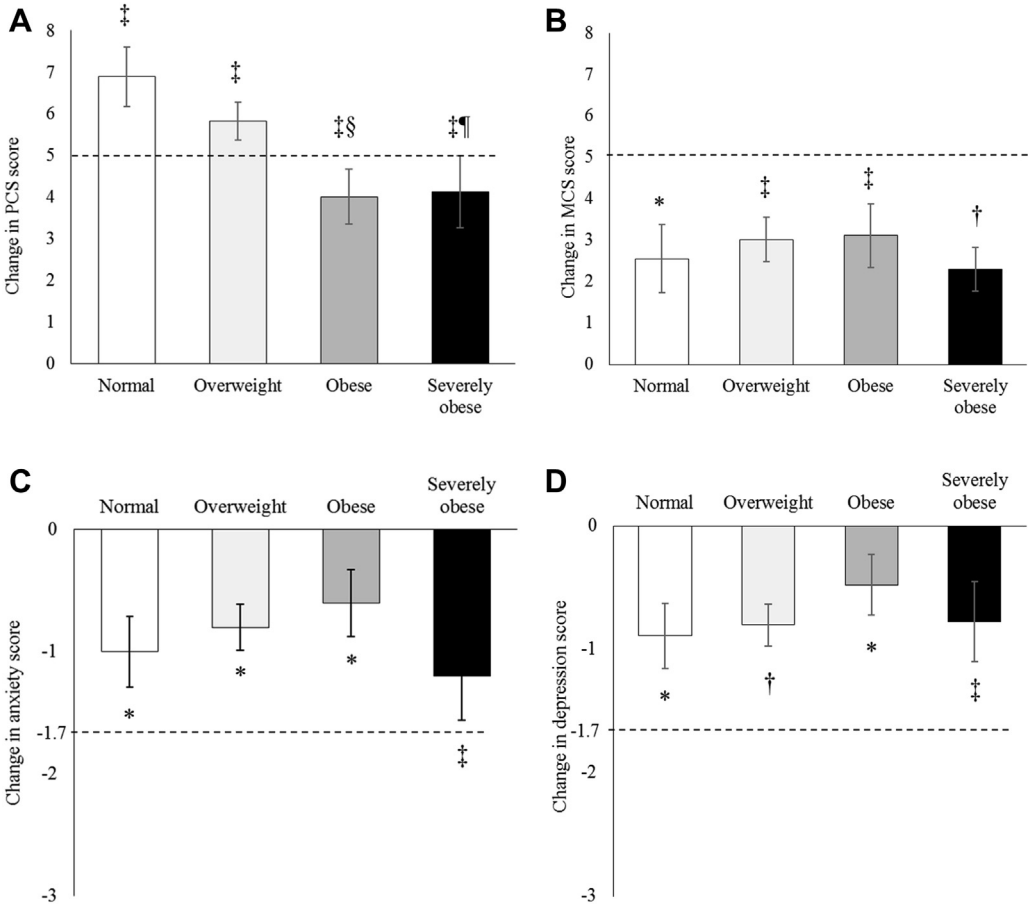

Figure 1. Changes in (**A**) Physical Component Summary (PCS) score, (**B**) Mental Component Summary (MCS) score, (**C**) Hospital Anxiety and Depression Scale (HADS) anxiety score, and (**D**) HADS depression score according to body mass index (BMI) categories. Data are reported as adjusted mean square ± standard error of the mean (SEM). The **dashed line** indicates a minimal clinically important difference (MCID). Significantly different from baseline: $^{*}P < 0.05$, $^{\dagger}P < 0.01$, $^{\ddagger}P < 0.001$. Significantly different from normal BMI: $^{\P}P < 0.05$, $^{\S}P < 0.01$.

myocardial infarction, and congestive heart failure in a CR population.[19] Collectively, inferior psychosocial and cardiometabolic health status at baseline, combined with a lack of clinically meaningful improvements during participation in a CR program in patients with obesity and severe obesity, support the need for more specific and attentive care of such patients to address their heightened risk of secondary events. Screening for psychosocial issues among those with severe

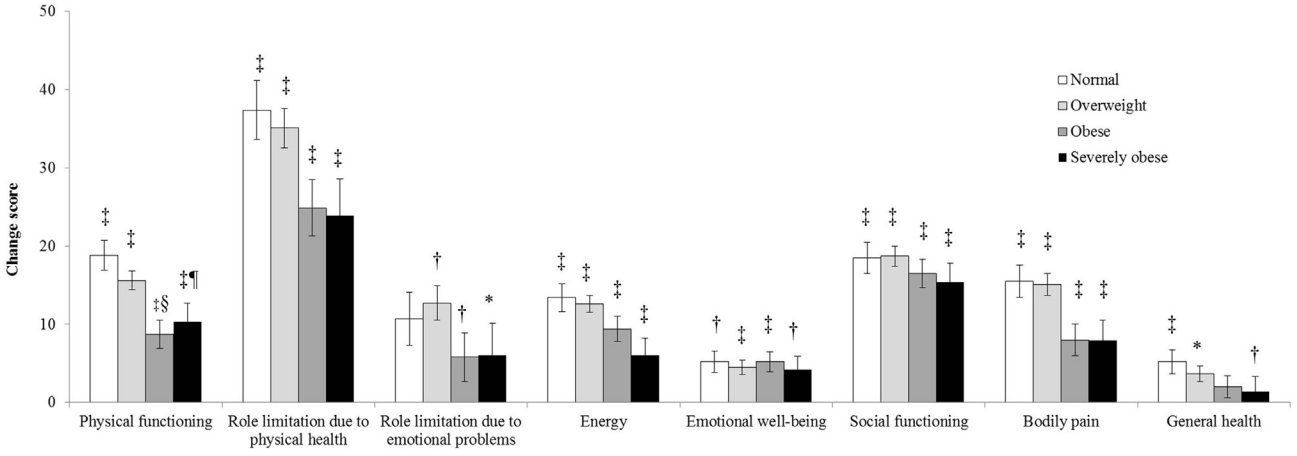

Figure 2. Changes in the 8 subscales of functional health and well-being scores. Data are reported as adjusted mean change ± SEM. Significantly different from baseline: $^{*}P < 0.05$, $^{\dagger}P < 0.01$, $^{\ddagger}P < 0.001$. Significantly different from normal BMI: $^{\P}P < 0.05$, $^{\S}P < 0.001$.

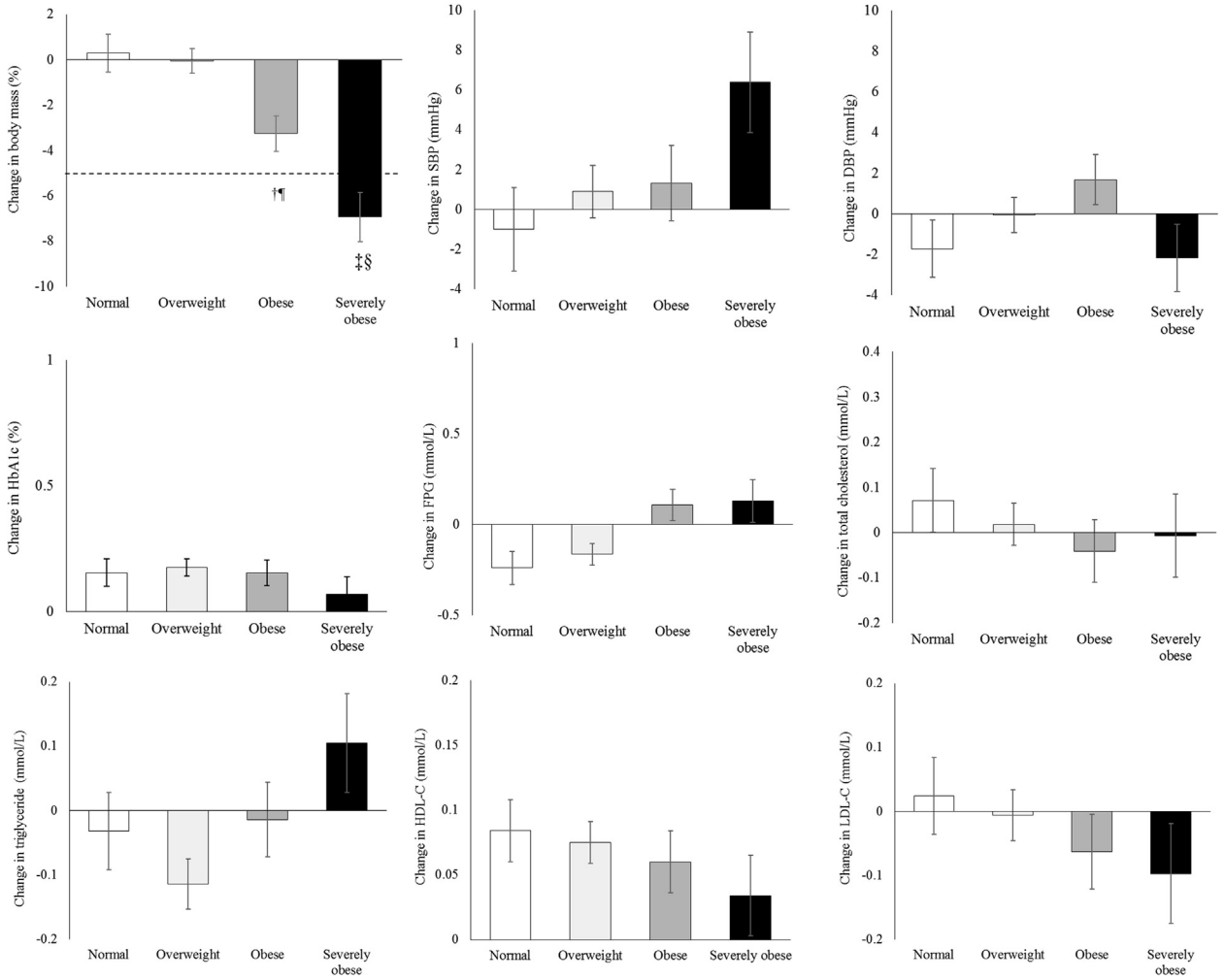

Figure 3. Changes in cardiometabolic health indicators according to BMI categories. Data are reported as adjusted mean square ± SEM. The **dashed line** indicates a clinically meaningful difference. Significantly different from baseline: $^{\dagger}P < 0.01$, $^{\ddagger}P < 0.001$. Significantly different from normal BMI: $^{\P}P < 0.01$, $^{\S}P < 0.001$. HbA1c, glycated hemoglobin A1c; BMI, body mass index; DBP, diastolic blood pressure; FPG, fasting plasma glucose; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; SBP, systolic blood pressure; SEM, standard error of the mean.

obesity at the time of entry to CR should be emphasized to facilitate enhanced adherence to healthy behaviours[30] in this high-risk group.

Psychosocial health indicators continue to receive increased recognition as critical patient-centered factors among those with CVD given the growing evidence of their significance in augmenting CVD risk.[4] In the present study, despite the statistically significant improvements, changes in the MCS scores, anxiety, or depression did not reach the MCID in any of our BMI groups. This highlights the need for improved strategies to assist the optimization of psychosocial well-being using the resources and sensitivities resident in most CR settings. Best practice guidelines for CR suggest routine screening for psychosocial health, yet many patients are not screened nor do they receive treatment when indicated.[32] With an increase in patients with obesity enrolled in CR demonstrating higher psychosocial risks, we need strategies to reduce their risks in a resource-efficient manner. There is evidence to suggest that CR combined with stress-management training effectively reduces psychosocial risk and improves medical conditions compared with CR alone.[33] More stringent screening processes to identify those who will benefit from additional CR services may increase the effects of CR on psychosocial health indicators in the rehabilitation setting.

As noted earlier, the changes in the PCS scores reached the MCID in overweight patients and patients with normal BMI but not in those with obesity or severe obesity. Although it is misleading to suggest that weight reduction is the only mechanism required to improve psychosocial health,[31] improvements in HR-QoL generally parallel the rate of weight reduction in patients with obesity.[34] In the current study, percent weight reduction was significantly greater in patients with obesity and severe obesity when compared with those with normal BMI, and the change in patients with severe obesity met the lower end of the clinically meaningful change (ie, 5%-10% reduction).[28] Despite significantly greater percent weight reduction in patients with obesity, markedly greater percent weight reduction is required to achieve the clinically meaningful reduction in the PCS score (23%, 95%

CI, 17.5-32.5).[35] The weight reduction measured in patients with obesity and severe obesity in our study may have been insufficient to improve PCS. Alternatively, unrealistic weight loss expectation may have resulted in frustration and contributed to smaller changes in PCS. It is important to note that the CR program we investigated did not specifically target weight loss. Because we adjusted for baseline differences to account for regression to the mean, we suspect that different physiological responses and energy requirement to perform the same task may have resulted in differential changes in percent body mass.

We explored whether the degree of improvements in the 8 subscales comprising the PCS scores was different in patients with obesity and severe obesity when compared with normal BMI and found significantly smaller improvements in "physical functioning." Although this item is not the only factor contributing to the PCS score, we speculate that a greater body mass prominently affected physical function. Because weight loss is difficult to achieve through CR,[18] alternative strategies specifically addressing "physical functioning" have the potential to improve HR-QoL of patients with obesity and severe obesity. Increasing fitness and range of motion during CR, for example, may play an important role in improving these parameters regardless of weight loss.

Despite the established effects of CR on indicators of cardiometabolic health,[13] few changes were found in the present study. At baseline, 86.3% of all patients were receiving cholesterol-lowering agents and total cholesterol and LDL-C concentrations were within target ranges in all BMI groups.[27] Additionally, although TG and glucose levels were significantly higher in patients with obesity and severe obesity, they were still within the recommended range.[27] It was unreasonable to expect further improvements in lipid levels in any group notwithstanding significantly differing degrees of weight loss.

Study limitations

There are several limitations to our findings. First, this study included only patients who completed CR. Typically, only a minority of patients with cardiac disease go on to participate in rehabilitation programs. Therefore, our study population is not necessarily representative of the broader cardiac patient population. Notably, patients with obesity are 56% less likely to adhere to CR than their nonobese counterparts;[36] it is reasonable to expect that the inclusion of patients who were lost to follow-up would attenuate the improvements noted in patients with obesity. Second, BMI is an aggregate measure of varying amounts of fat and lean mass and their anatomic distribution. The lack of the discriminatory power of BMI to differentiate fat, lean mass, and fat distribution may have implications for our findings. However, because BMI is more strongly associated with fat mass when BMI is high,[37] we speculate the characteristics associated with severe obesity found in this study are primarily due to large fat mass. Third, cardiorespiratory fitness (CRF) data were not available. CRF is a major factor affecting prognosis in CVD.[11] Evidence suggests that increasing CRF may be a more important and effective treatment target than weight loss.[38] A strong association between CRF and emotional distress has been established.[39] Considering that obesity is a negative predictor of post-CR CRF,[40] smaller changes in HR-QoL in patients with obesity and severe obesity may be due to smaller changes in CRF. Future studies with CRF measures will permit further examinations of the changes in psychological and cardiometabolic health experienced by patients with obesity participating in CR. Last, we collapsed class II and III obesity because of the small number of patients in these groups. Future analyses with enough power to detect characteristics specific to class II and class III obesity may lead to more precise strategies to improve the well-being of these patients.

Conclusions

The benefits and goals of CR are linked to the clinical and anthropometric characteristics of an individual patient participating in CR. We can anticipate an increase in the prevalence of patients with more advanced obesity participating in CR. Such patients will present with reduced levels of psychosocial health and more adverse cardiometabolic challenges, and demonstrate smaller improvements in self-perception of physical health. Current programs of CR that provide a standardized approach to all patients do not appear to provide the same benefits to patients with obesity as to those of normal weight. The delivery of more individualized management strategies to address the challenges presented by obesity may reduce secondary cardiovascular events among this burgeoning patient population.

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Disclosures

The authors have no conflicts of interest to disclose.

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