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Original Article

Women's Improvements in Cardiorespiratory Fitness Following Cardiac Rehabilitation Differ by Body Mass Index Category

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ABSTRACT

Background: Improving women's cardiovascular outcomes requires optimizing cardiorespiratory fitness (CRF), as higher CRF predicts improved mortality in people with cardiovascular disease (CVD). As such, increasing CRF is a key goal of cardiac rehabilitation (CR). This study assesses the potential influence of body habitus, assessed by body mass index (BMI), on improvements in CRF in women with CVD.
Methods: Women (18+ years) diagnosed with CVD who completed a 12-week exercise-based CR program between 1996 and 2016 were included in this retrospective analysis. Women completed a symptom-limited graded exercise test before CR and at CR completion to determine CRF via peak metabolic equivalents (METs). Women were categorized by baseline BMI: normal = 18.5 to 24.9 kg/m^2, overweight = 25.0 to 29.9 kg/m^2, and obese ≥ 30 kg/m^2. Mixed analysis of covariance (ANCOVA) was performed to evaluate the impact of BMI classification on ΔMETs at 12 weeks.

RÉSUMÉ

Contexte : L'amélioration des pronostics cardiovasculaires chez les femmes passe par l'optimisation de la condition cardiorespiratoire (CCR), car une CCR élevée est prédictive d'une mortalité réduite chez les personnes atteintes de maladie cardiovasculaire (MCV). L'amélioration de la CCR est donc un objectif clé de la réadaptation cardiaque (RC). Cette étude évalue l'influence potentielle de la constitution physique, évaluée par l'indice de masse corporelle (IMC), sur l'amélioration de la CCR chez les femmes atteintes de MCV.
Méthodes : Les femmes (18 ans et plus) diagnostiquées avec une MCV qui ont suivi un programme de RC basé sur l'exercice physique durant 12 semaines, entre 1996 et 2016, ont été incluses dans cette analyse rétrospective. Les femmes ont effectué un test d'exercice gradué limité par les symptômes, avant la RC et à la fin de la RC, pour déterminer la CCR par le biais d'équivalents métaboliques (MET) maximaux. Les femmes ont été classées en fonction de leur IMC de

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See page 532 for disclosure information.

The physical and psychosocial complications of obesity (body mass index [BMI] ≥ 30 kg/m^2) may hinder improvements in women's cardiorespiratory fitness (CRF) in cardiac rehabilitation (CR), a highly effective recommended standard treatment for reduction of cardiovascular (CV) risk factor. Both female sex[1-4] and a higher BMI[2,5] have been associated with

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Results: Data from 1313 women (mean age = 62 ± 11 years) were analyzed. Results from mixed ANCOVA indicated a significant time (pre-CR, 12 weeks) by BMI category interaction (F [2,1307] = 3.20, $P = 0.041$, $\eta p^2 = 0.005$). Follow-up analyses of variance (ANOVAs) showed significant improvements in ΔMETs in women with normal and overweight BMI categories (standard mean difference =1.03, n = 454 and 0.92, n = 461, respectively, $P < 0.001$). However, ΔMETs among women classified as obese was nonsignificant using a Bonferroni-adjusted alpha of 0.017 (standardized mean difference [SMD] = 0.79, $P = 0.028$; n = 398).

Conclusions: A 12-week exercise-based CR program increased CRF in women classified as normal or overweight by BMI, whereas those with obesity did not realize similar improvements. Women with obesity may need tailored strategies to increase their improvements in CRF in CR.

Clinical Trial Registration: REB18-0083.

base: normal = 18,5 à 24,9 kg/m^2, surpoids = 25,0 à 29,9 kg/m^2, et obésité ≥ 30 kg/m^2. Une analyse mixte de la covariance (ANCOVA) a été réalisée pour évaluer l'impact de la classification de l'IMC sur les ΔMET à 12 semaines.

Résultats : Les données de 1 313 femmes (âge moyen = 62 ± 11 ans) ont été analysées. Les résultats de l'ANCOVA mixte ont indiqué une interaction significative entre le temps (avant la RC, 12 semaines) et la catégorie d'IMC (ratio F [2,1307] = 3.20, $p = 0,041$, taille de l'effet $\eta p^2 = 0,005$). Les analyses de variance (ANOVA) de suivi ont montré des améliorations significatives des ΔMET chez les femmes ayant un IMC normal ou en surpoids (différence moyenne standard = 1,03, n = 454 et 0,92, n = 461, respectivement, $p < 0.001$). Cependant, chez les femmes classées comme obèses, les ΔMET n'étaient pas statistiquement significatives en utilisant une valeur alpha ajustée de Bonferroni de 0,017 (différence moyenne standardisée = 0,79, $p = 0,028$, n = 398).

Conclusions : Un programme de RC de 12 semaines basé sur l'exercice physique a augmenté la CCR chez les femmes classées comme normales ou en surpoids selon leur IMC, alors que celles souffrant d'obésité n'ont pas obtenu d'améliorations similaires. Les femmes souffrant d'obésité pourraient avoir besoin de stratégies adaptées pour améliorer leur CCR dans le cadre d'un programme de RC.

Numéro d'enregistrement de l'essai clinique : REB18-0083.

smaller improvements in physical functioning and suboptimal adherence to structured exercise programs, including CR.[6] Despite the potential for obesity to limit the benefits of CR for women, the impact of differing BMI categories on CRF improvement in women participating in CR has not been well examined. Identifying groups that may require tailored strategies to improve their outcomes is an important first step, especially given the increasing prevalence of obesity among women in CR.[7]

Cardiovascular diseases (CVDs) are the leading causes of premature death for women in 97 countries including Canada and the United States.[8] Women with CVD have poorer morbidity and mortality outcomes compared with men.[9,10] Differences in outcomes are attributable to sex-specific physiology (eg, hormones), sex-specific pathophysiology (eg, diffuse arterial disease), gender characteristics (eg, social roles), and delays in diagnosis and treatment among women.[11-17] As such, sex- and gender-informed research is needed in all areas of women's heart health, including primary and secondary risk reduction.[9,10,18]

CRF is considered a vital sign as it predicts long-term CV outcomes and survival in adults.[19-22] In women, CRF independently predicts all-cause mortality,[23] and women appear to gain greater health outcomes from improving CRF compared with men.[24] Women with CVD, who improve their CRF by 1 metabolic equivalent (MET) can reduce all-cause mortality rates up to 17% to 25%.[25,26] Improving CRF is a key component of secondary prevention in CR, as higher CRF is associated with better CV outcomes..

CR is an interdisciplinary CVD risk reduction treatment model that includes risk-factor modification, psychosocial support, nutrition counselling, education, and exercise training.[27] Although CRF improvement is central to CR, it is achieved alongside other essential strategies, such as medication optimization, dietary counselling, psychosocial support, and return to work planning that together aim to enhance patients' long-term adherence, quality of life, and CV health. CR improves CRF, reduces hospitalizations, and lowers mortality.[25,28-30] Women who complete CR have a 64% relative risk reduction in mortality compared with women who did not complete CR programs.[31] Although improving CRF is a key goal of CR, not all women improve this measure. Results from a 13-year retrospective analysis suggest that 22% of people who attend CR do not improve their CRF, and 17% have low improvements associated with female sex, diabetes, lower baseline CRF, hostility, and an increased waist circumference.[1] One plausible patient characteristic that may limit improvements in CRF in CR is body habitus, although research is limited. Women with higher waist circumference, on average, have lower improvements in CRF following participation in CR.[32] Women with obesity who complete CR have had smaller improvements in self-reported physical functioning compared with those in the normal BMI category.[5] Identifying participants who are less likely to experience improvements in CRF in standard CR programs requires further study. Thus, the primary purpose of this study was to determine if the completing a 12-week CR program produced similar improvements in CRF in women with differing BMI categories.

Methods

Study population

This study is a secondary analysis of data from a retrospective study linking clinical and administrative databases, as previously described.[2] Clinicians collected data as part of standard care for individuals with a history of CVD referred to an outpatient CR program in Calgary, Alberta, Canada (TotalCardiology Rehabilitation [TCR]), and through the Alberta Provincial Project for Outcome Assessment in Coronary Heart Disease (APPROACH). The APPROACH

database includes prospectively collected clinical information and outcomes of all patients undergoing cardiac catheterization or revascularization in Alberta through linkages to the Discharge Abstract Database (DAD), National Ambulatory Care Reporting System (NACRS), and Vital Statistics. Researchers linked the APPROACH data with TCR data using personal health care numbers. *The data underlying this article cannot be shared publicly because of the consent agreement to maintain the privacy of the individuals who participated in the study.* The final database used for this study included women who were referred to and completed the TCR program between January 1996 and March 2016; were 18 years of age or older; and had baseline CRF, height, weight, and waist circumference data available. Completion of the CR program was defined as completing both a baseline and 12-week post-CR assessment.

CR Program

Participants were offered a 12-week comprehensive CR program that included 1 hour of supervised exercise twice weekly. If able, patients were encouraged to perform independent exercise sessions 2 to 3 additional days per week. Participants underwent a symptom-limited graded exercise test, using a Standard or Modified Bruce protocol on a treadmill, at baseline and following CR completion (12 weeks). Peak METs were used to quantify CRF, calculated according to the protocol and mode of exercise by established equations.[33,34] An exercise specialist measured body weight and height using a calibrated electronic scale and waist circumference using a tape measure placed halfway between bottom of ribs and top of hips.

Each supervised exercise session began with a 5-minute warm-up, followed by 20 to 60 minutes of steady-state aerobic training at a moderate intensity (60%-80% of heart rate reserve)[33] followed by a 5-minute cool down. A multidisciplinary team assisted with risk-factor management including support with nutrition, psychosocial factors, medication adherence, and smoking cessation. A home-based CR program was offered as an alternative to participants who had difficulty attending clinic-based CR. The home program consisted of exercise training at home or in the community with weekly health coaching follow-up support by phone calls from a nurse or exercise professional.

Measures

Sociodemographic and clinical covariates

Baseline demographic characteristics (age, sex), anthropometric measurements (height [cm], weight [kg], and waist circumference [cm]), resting blood pressure (mm Hg), cholesterol (high-density lipoprotein [HDL], low-density lipoprotein [LDL], total cholesterol, triglycerides; mmol/L), smoking status, and information about the CR program (completion of clinic-based or home-based CR) were obtained from the TCR database. As only 37% of the participants had hemoglobin A1C levels available, this datum was not

Table 1. Characteristics of women in cardiac rehabilitation by body mass index (N = 1313)

Baseline Characteristic	Normal n = 454	Overweight n = 461	Obese n = 398	ANOVA or χ^2	*P*
Age (years)	63 (12)	64 (11)	59 (10)*	F(2) = 17.39	<0.001
BMI (kg/m^2)	22.5 (1.7)	27.3 (1.4)	34.9 (4.3)*	F(2) = 2189	<0.001
Home program (Yes)	97 (21%)	122 (26%)	92 (23%)	χ(2) = 4.32	0.115
Resting heart rate (bpm)	70 (13)	70 (12)	71 (12)	F(2) =2.0	0.136
Resting SBP (mm Hg)	113 (18)*	117 (18)	116 (17)	F(2) = 4.69	0.009
Resting DBP (mm Hg)	69 (10)	70 (10)	72 (9)*	F(2) = 8.07	<0.001
HDL (mmol/L)	1.46 (0.4)	1.31 (0.4)	1.19 (0.3)*	F(2) = 46.20	<0.001
LDL (mmol/L)	2.4 (1.0)	2.4 (1.08)	2.5 (1.0)	F(2) = .303	0.739
Triglycerides (mmol/L)	1.7 (9.4)	1.5 (0.7)	1.8 (1)	F(2) = .546	0.579
Waist (centimetres)	81 (7.5)	94 (7.4)*	109.4 (10.6)*	F(2) = 1146	<0.001
Peak metabolic equivalents	6.73 (2.0)*	6.21 (1.75)*	5.61 (1.64)*	F(2) = 39.5	<0.001
Comorbidities					
Diabetes (type 1 and 2)	55 (12.1%)	81 (17.6%)	118 (29.6%)*	χ(2) = 43.2	<0.001
COPD	47 (10.4%)	58 (12.6%)	48 (12.1%)	χ(2) = 1.19	0.550
Malignancy	19 (4.6%)	29 (6.3%)	14 (3.5%)	χ(2) = 4.09	0.129
CHF	51 (11.2%)	36 (7.8%)	32 (8.0%)	χ(2) =3.98	0.137
PVD	16 (3.5%)	16 (3.5%)	18 (4.5%)	χ(2) = 0.798	0.671
Hypertension	246 (55.1%)	295 (64%)	289 (72.6%)*	χ(2)=30.99	<0.001
Hyperlipidemia	250 (55.1%)	293 (63.6%)	253 (63.6%)	χ(2) = 9.51	0.009
Liver/gastric disease	37 (8.1%)	45 (9.8%)	28 (7.0%)	χ(2) = 2.11	0.347
CVD	21 (4.6%)	20 (4.3%)	5 (1.3%)	χ(2) = 8.59	0.014
Renal disease	3 (0.7%)	8 (1.7%)	6 (1.5%)	χ(2) = 8.59	0.014
Current smoker	86 (18.9%)	105 (22.8%)	96 (24.1%)	χ(2) = 3.68	0.159
Former smoker	113 (24.9%)	113 (24.5%)	106 (26.6%)	χ(2) = 0.566	0.753
Family history CVD	143 (31.5%)	165 (35.8%)	138 (34.7%)	χ(2) = 2.04	0.361
Previous MI	32 (7%)	44 (9.5%)	50 (12.6%)	χ(2) = 7.4	0.024
STEMI	134 (29.5%)	120 (26%)	107 (26.9%)	χ(2) = 1.5	0.472
NSTEMI	102 (22.5%)	98 (21.3%)	79 (19.8%)	χ(2) = 0.868	0.648

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

ANOVA, analysis of variance; BMI, body mass index; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; CVD, cardiovascular disease; DBP, diastolic blood pressure; HDL, high-density lipoprotein; LDL, low-density lipoprotein; MI, myocardial infarction; NSTEMI, non−ß†-elevation myocardial infarction; PVD, peripheral vascular disease; SBP, systolic blood pressure; STEMI, ST-elevation myocardial infarction.

*Post hoc comparisons indicate the group(s) that differed significantly ($P < 0.001$).

Table 2. Mixed ANCOVA (Time × BMI category): N = 1313

Source of variance	SS	Df	MS	F	*P*	np^2
Within subjects						
Time	22.176	1	22.176	40.646	< 0.001	0.030
Time * age	.029	1	.029	.053	0.818	0.000
Time * diabetes	4.350	1	4.350	7.973	0.005	0.006
Time * hypertension	1.917	1	1.917	3.513	0.061	0.003
Time * BMI category	3.488	2	1.744	3.196	0.041	0.005
Error (time)	713.101	1307	0.546			
Between subjects						
BMI category	759.17	2	379.58	83.99	< 0.001	0.114
Error	5906.547	1307	4.519			

ANCOVA, analysis of covariance; BMI, body mass index.

included. The APPROACH database was used to derive information regarding clinical covariates including comorbidity status (eg, type 2 diabetes, hypertension, hyperlipidemia, liver disease, gastrointestinal disease, cerebrovascular disease, renal disease, congestive heart failure [CHF], chronic obstructive pulmonary illness [COPD], malignancy and peripheral vascular disease [PVD], and previous myocardial infarction [MI]).

CRF. CRF was estimated by peak MET achieved on the symptom-limited maximal exercise test. In CR, increasing CRF by one MET is associated with a 17% to 25% reduction in mortality, and as such is used as a clinically meaningful benchmark of change in this study.[24,25]

BMI. Patients were categorized into normal (BMI = 18.5-24.99 kg/m^2), overweight (BMI = 25.00-29.99 kg/m^2), and obese (BMI ≥ 30 kg/m^2) groups based on calculated BMI. Patients who were underweight (BMI < 18.5) were excluded from the analysis as the sample included only 24 women.

Waist circumference. Patients were also grouped into 3 categories based on waist circumference: no risk (< 80 cm), increased risk (80-87 cm) and substantially increased risk (> 88 cm).[35,36]

Statistical analysis

Independent samples Student's *t*-tests were used to compare women in the database who had BMI data available (included) and those who did not (excluded). Descriptive statistics were performed to characterize the study sample (eg, mean [M], standard deviation [SD], proportion). Baseline characteristics of the sample were compared among the 3 BMI categories using χ^2 test for categorical variables and 1-way analysis of variance (ANOVA) for continuous variables. Baseline variables that were significantly different between BMI category groups were entered as covariates into the primary analyses. To assess the association of Time and BMI category with improvements in CRF at 12-weeks, a 2 (Time; baseline and 12-week) × 3 (BMI: normal, overweight, obese) repeated measure analysis of covariance (ANCOVA) was performed. Age, diabetes, and hypertension were included in the model as covariates. Paired-sample Student's *t*-tests were performed to determine the standard mean difference in METs from baseline to 12 weeks.

A secondary aim of the study was to assess the changes in women's CVD risk factors (cholesterol levels, blood pressure, heart rate, weight, waist circumference) pre-to post-CR by BMI category using paired sample Student's *t*-tests to evaluate absolute changes in CV risk factors from pre- to post-CR. In addition, given recent calls for the use of non-BMI measures of body habitus in CVD research,[37] an exploratory mixed ANCOVA was also performed substituting waist circumference risk category for BMI category.

Results

Sample characteristics

A total of 2165 women in the database completed the 12-week CR program during the study timeframe. We excluded 798 women missing BMI data, 30 women missing waist circumference data and the small group of women who were underweight pre-CR (BMI < 18.5 kg/m^2, n = 24). A total of 1313 women were included in the analysis (Table 1). Student's *t*-tests indicated that women who were excluded from the analyses because of missing BMI data were, in general,

Table 3. Follow-up 1-way ANOVA change in METs by BMI Category (N = 1313)

BMI category	Source of variance	SS	df	MS	F	*P*	np^2
Normal range	Time	13.500	1	13.500	22.84	**<**.001	0.048
	Time * age	0.272	1	0.272	0.460	0.498	0.001
	Time * diabetes	1.713	1	1.713	2.893	0.090	0.006
	Time * hypertension	0.755	1	0.755	1.276	0.259	0.003
	Error (time)	266.404	450	0.592			
Overweight	Time	7.183	1	7.183	14.404	**<**.001	0.031
	Time * age	0.076	1	0.076	0.151	0.697	0.000
	Time * diabetes	0.346	1	0.346	0.695	0.405	0.002
	Time * hypertension	0.010	1	0.010	0.020	0.887	0.000
	Error (time)	227.890	457	0.499			
Obese	Time	2.676	1	2.676	4.877	0.028	0.012
	Time * age	0.496	1	0.496	0.904	0.342	0.002
	Time * diabetes	2.758	1	2.758	5.027	0.026	0.013
	Time * hypertension	2.326	1	2.326	4.240	0.040	0.011
	Error (time)	216.146	394	0.549			

Statistically significant at the Bonferroni-adjusted $\alpha = 0.017$.

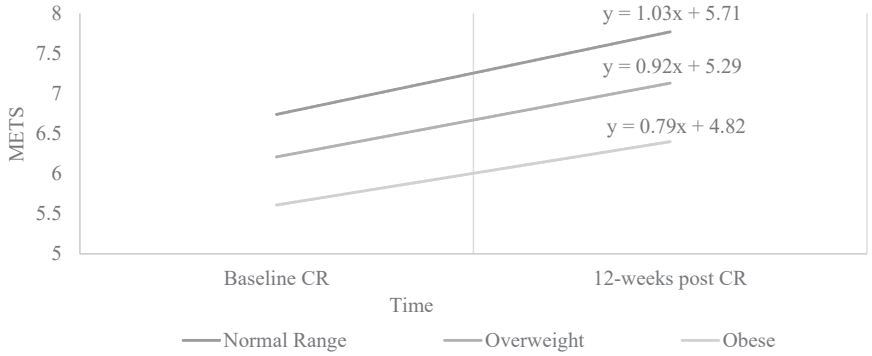

Figure 1. Cardiorespiratory fitness of women with CVD at baseline to 12-week post CR based on BMI category. Normal range: 18.5-24.99 kg/m^2; overweight: 25.0-29.99 kg/m2; obese: ≥ 30.0 kg/m^2; adjusted for age. CR, cardiac rehabilitation; METs, peak metabolic equivalents.

healthier, with higher baseline mean peak METs (M ± SD; 6.5 ± 1.9 vs 6.2 ± 1.8, $P < 0.001$), lower LDL levels (2.18 ± 0.97 vs 2.43 ± 1.00, $P < 0.001$), and total cholesterol (TC) levels (4.28 ± 1.47 vs 4.43 ± 1.56, $P = 0.007$). Although the excluded subjects had higher blood pressure (SBP 126 ± 21.3 vs 116 ± 18.4, $P < 0.001$), DBP was 75 ± 9.80 vs 70 ± 9.99, $P < 0.001$.

Sociodemographic and clinical characteristics of the sample are presented in Table 1. The sample consisted of 34.6% of women with normal weight, 35.1% in the overweight category, and 30.3% with obesity. The mean age of the sample was 62 years (± 10.90). Women with obesity were younger on average (59 years) than both the overweight (63 years) and normal weight (64 years) groups ($P < 0.001$) and had lower HDL and higher DBP (albeit within a normal range), compared with the normal weight group ($P < 0.001$); see Table 1.

Improvements in CRF according to BMI group

Results of the mixed ANCOVA evaluating the influence of BMI on CRF improvements during CR are presented in Table 2. There was a statistically significant Time × BMI category interaction, F (2,1307) = 3.20, $P = 0.041$, $np^2 = 0.005$, indicating that change in CRF from baseline to 12 weeks differed by women's BMI categories. The interaction was broken down in a series of 1-way within-subjects ANOVA with statistical significance evaluated using a Bonferroni-adjusted alpha = 0.5/3 = 0.017 (Table 3). The follow-up ANOVAs revealed the interactions among age, diabetes, and hypertension were not a significant source of variance in any of the BMI categories. Whereas improvements in CRF over the 12 weeks were statistically significant among women in the normal and overweight categories, follow-up ANOVAS indicated that CRF did not improve in the obese category (Table 3). In the normal-weight group, women's peak METs improved from baseline (6.74 ± 2.05) to 12 weeks (7.77 ± 1.98), F = 22.8, $P < 0.001$, $np^2 = 0.048$. Women in the overweight group displayed a similar improvement in peak METs from baseline to 12 weeks (6.21 ± 1.78 to 7.13 ± 1.81, F = 14.4, $P < 0.001$, $np^2 = 0.031$). However, the group of women with obesity did not experience a statistically significant improvement in peak METs at 12 weeks (5.61 ± 1.64 to 6.40 ± 1.71 METs, F = 4.9, $P = 0.028$, $np^2 = 0.012$).

In this sample, women with baseline BMI in the normal range displayed clinically meaningful improvements in CRF (ie, > 1.0 peak METs increase), whereas women in the overweight and obese groups did not (Figure 1, Table 4). All 3 groups displayed comparable magnitudes of change (Cohen's d = 1.09, 1.00, and 1.06 for the normal, overweight, and obese groups, respectively, in which d > 0.8 is considered a large effect size.[38] Thus, CR had a large positive effect on CRF, yet women with overweight and obesity did achieve the target of improving CRF by 1 peak MET.

Table 4. Comparison of peak METs at baseline and 12 weeks after CR in women based on BMI category (N = 1313)

	METs		
BMI category	Baseline CR METs	12-week METs	Mean difference
Normal range (n = 454) BMI 18.5-24.99 kg/m^2	6.74 (2.05)	7.77 (1.98)	1.03*
Overweight (n = 461) BMI 25.0-29.99 kg/m^2	6.21 (1.78)	7.13 (1.80)	0.92*
Obese (n = 398) BMI ≥ 30.0 kg/m^2	5.61 (1.64)	6.40 (1.71)	0.79

Peak metabolic equivalents (METs) reported number (standard deviation).

BMI, body mass index; CR, cardiac rehabilitation; METs, metabolic equivalents.

*Paired Student's *t*-test $P < 0.001$ level.

Absolute changes in risk factors over 12 weeks

Absolute changes in risk factors from baseline to 12 weeks are summarized in Table 5. On average, women's cholesterol levels, heart rate, and waist-circumference measurements were significantly lower following the 12-week program, regardless of their BMI classification. On average, women in the normal BMI group gained 0.37 kg from baseline to 12 weeks ($P = 0.008$), whereas there was no significant weight change in the other BMI groups.

Improvements in CRF according to waist circumference

Changes in peak METs from baseline to 12 weeks according to waist-circumference groups are presented in Figure 2 and Table 6. The sample consisted of 207 women in the "no risk"

Table 5. Change in risk factors from baseline to 12-week follow-up after CR by BMI category

Measurements	Normal				Overweight				Obese			
	Baseline	12-week	Change	*P*	Baseline	12-week	Change	*P*	Baseline	12-week	Change	*P*
Systolic blood pressure (mm Hg)	113 (17.6)	114 (18.5)	1.7 (18.6)	0.055	116 (17.8)	118 (17.2)	2.00 (18.1)	0.024	116 (17.0)	116 (15.4)	0.66 (16.1)	0.440
Diastolic blood pressure (mm Hg)	69 (10.0)	69 (9.6)	0.01 (10.1)	0.985	70 (9.4)	70 (8.4)	0.01 (9.4)	0.984	71 (9.4)	71 (9.0)	0.14 (10.4)	0.792
Heart rate (beats per minute)	70.0 (13.0)	69 (12.0)	−1.5 (11.4)	0.006	70 (12.1)	69 (11.7)	−1.75 (12.3)	0.004	71 (12.2)	70 (11.4)	−1.30 (10.8)	0.023
Low-density lipoprotein (mmol/L)	2.4 (1.00)	1.9 (.8)	-0.5 (0.9)	<0.001	2.42 (1.0)	1.9 (0.8)	−0.50 (1.0)	<0.001	2.41 (1.0)	1.83 (.8)	-0.59 (1.0)	<0.001
High-density lipoprotein (mmol/L)	1.5 (0.4)	1.5 (.4)	-0.05 (0.3)	0.001	1.35 (0.4)	1.4 (0.4)	−0.07 (0.2)	<0.001	1.17 (0.3)	1.22 (.3)	−0.05 (0.2)	<0.001
Triglycerides (mmol/L)	1.4 (0.7)	1.3 (0.6)	−0.1 (0.6)	0.004	1.42 (0.7)	1.26 (0.6)	−0.16 (0.6)	<0.001	1.79 (1.0)	1.49 (.8)	−0.29 (0.7)	<0.001
Waist (cm)	81.5 (7.6)	80.7 (9.1)	−0.8 (6.5)	0.022	93.9 (7.4)	93.2 (7.6)	−0.63 (4.7)	0.010	110.2 (10.6)	109.2 (10.8)	−0.98 (4.8)	<0.001
Weight (kg)	59.7 (6.7)	60.1 (7.0)	0.4 (2.7)	0.008	72.3 (7.0)	72.5 (7.9)	0.15 (2.9)	0.318	93.8 (14.3)	93.7 (14.7)	−0.54 (3.6)	0.790

P based on paired sample Student's *t*-test. Data are reported as mean (standard deviation).
BMI, body mass index; CR, cardiac rehabilitation.

waist category, 287 women with "increased risk," and 819 women with "substantially increased risk." Results of the exploratory mixed ANCOVA examining the potential interaction between time and waist circumference on CRF improvement found main effects of both time ($F [1,1307] = 38.93$, $P < 0.001$, $np^2 = 0.029$) and waist risk category ($F [2,1307] = 70.19$, $P < 0.001$, $np^2 = 0.097$] on CRF. The Time × waist circumference category interaction was nonsignificant ($P = 0.439$), indicating the magnitude of CRF improvements did not depend on baseline waist circumference.

Discussion

This study sought to evaluate measurable differences in CRF improvements across BMI categories in CR, building on previous research suggesting that patients with obesity experience smaller improvements in self-reported physical functioning compared with those in the normal BMI category.[39] Our findings indicate that women classified as obese achieved smaller CRF improvements compared with those in lower BMI categories, underscoring the need for tailored strategies to support equitable cardiovascular benefits for all BMI groups. To support improvements in CRF, clinicians require a nuanced understanding of the barriers that may limit women's CRF improvements CRF in CR.[40] For instance, it has been suggested that women may need a greater duration in CR to achieve clinically meaningful outcomes.[41] Alternatively, innovative delivery models, such as remote and virtual approaches, have been proposed.[42] Although time and accessibility may be a factor, the solution may be more complex among women with obesity.

In a large (n = 20,239) prospective study of healthy White men and women, researchers found that higher BMI, older age, gender (female), and lower physical activity were reported to be the most important factors associated with CRF.[43] Participants with obesity achieved lower peak METs relative to other BMI categories, even if they reported the same amount physical activity.[43] The researchers suggested that people with obesity who meet or exceed physical activity recommendations might not overcome the negative impact of BMI on CRF.[43] In the current study, a range of metabolic, psychosocial, and behavioural factors may have interfered with the ability of women in the obese category to achieve significant improvements in CRF in CR. Although obesity-related differences in treatment response could not be accounted for by age or comorbidities such as diabetes or hypertension in this study, past research has found that diabetes is associated with impaired exercise performance.[44]

In addition to the metabolic complications of obesity, women with obesity are particularly at risk for having lower quality of life, socioeconomic status, and experiencing weight bias, internalized weight bias (IWB), stigmatization, and discrimination compared with women without obesity, all of which are associated with poorer health and increased mortality.[45-51] Additional research is needed to understand how or if these factors contribute as underling mechanisms to lower CRF both pre- and post-CR.

In addition to identifying barriers, identifying optimal improvements of CRF in CR is debated. All women in this study did achieve comparably large magnitudes of change in mean CRF from baseline to 12 weeks, albeit not statistically

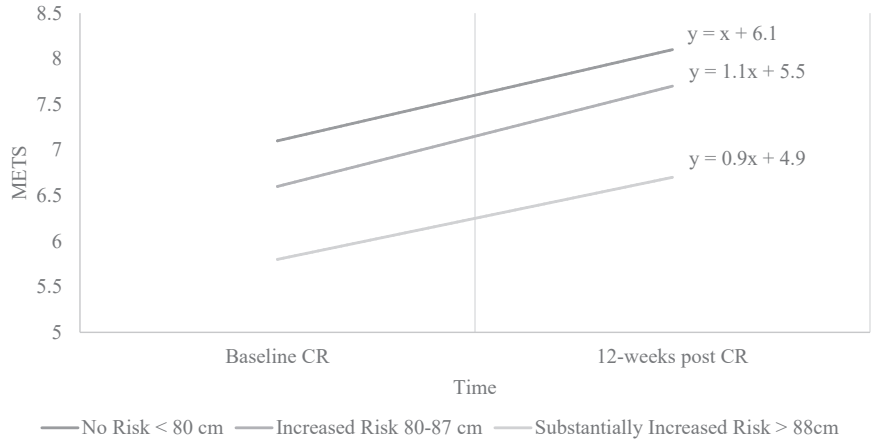

Figure 2. Cardiorespiratory fitness of women with CVD at baseline to 12-week postexercise-based CR program based on waist category. CR, cardiac rehabilitation; CVD, cardiovascular disease; METs, peak metabolic equivalents; adjusted for age.

significant. This is clinically significant because even small increases in activity and CRF are linked to improved health outcomes independent of body weight.[52] In addition, the completion of CR and exercise training offers potential health benefits both for CVD and management of obesity. Current guidelines for adult obesity clinical practice recommend the core treatment for obesity should include medical nutrition therapy and physical activity.[53] Physical activity in obesity treatment recommendations include 30 to 60 minutes of moderate-to-vigourous aerobic activity most days of the week,[53] in keeping with CR recommendations of minimum of 150 minutes of weekly moderate aerobic activity.[33] Although exercise recommendations are consistent, determining an optimal clinical target for CRF improvement during CR may be important in risk reduction for women with CVD.

A 1-MET improvement is used as a clinically meaningful benchmark of improvement,[25,26] and 58% of this sample did not achieve this target. This may be in part related to women being relatively fit at baseline and already achieved their optimal CRF, but it may also be related to other unmeasured factors. In this study, 35% of women with obesity achieved 1-MET improvement compared with 45% and 43% of the women with normal weight and overweight BMI groups.

Age and baseline CRF levels vary in CR participants, and so, an absolute 1-MET increase may not be the best measure of successful CV risk reduction in women in CR. Alternatively, exercise outcome targets could be determined by using a model that predicts optimal CRF (nomogram) for women of differing ages. Gulati et al. [54] developed a nomogram for CRF in women based on age, in both sedentary and active women with and without symptoms. Normal values were based on 5721 healthy women and 4471 women being investigated for suspected CVD who were followed for 15 to 20 years. In this nomogram the greater the deviation from the normal predicted MET value, the greater the CVD-related and all-cause mortality risk. For example, a 60-year-old woman who achieved 7 METs on a Bruce protocol would have achieved 100% of her predicted CRF, whereas a 40-year-old woman who achieved 7 METs would have achieved 72% of her predicted CRF for her age.[54] Achieving less than 85% of predicted CRF doubled women's chance of dying from CVD and all-cause mortality (hazard ratio [HR], 2.02; $P < 0.001$; HR, 2.37; $P < 0.001$, respectively).[54] Women $\leq$ 55 years of age who achieve 2 METs lower than their predicted CRF had the highest mortality rate.[54] This tool has prognostic value at baseline, but it is not known if improving CRF to the target/normal age-based values is associated with improved outcomes.[54] Future research could assess using precise functional targets from this nomogram and determine whether this tool aids participants' long-term goals.

Interestingly, most women in this study (84%) had a waist measurement associated with elevated CV risk. This is not surprising, as waist circumference is known to be a strong predictor of CVD.[55-57] Although other researchers have found abdominal obesity is associated with lower improvements in CRF in CR,[32] no difference in CRF outcomes associated with waist circumference were observed in this cohort. Notably, women in the highest waist-circumference category had lower peak METs compared with those in the 2 other waist-circumference categories. Given that baseline peak METs is the single most important predictor of CV outcomes and mortality in CR,[20] the association between abdominal adiposity and baseline CRF requires further study.

Table 6. Comparison of peak METs at baseline and 12 weeks after CR in women based on waist circumference category (N =1313)

Waist circumference category	Peak METs		
	Baseline-CR METs	12-week METs	Mean change
No risk, < 80 cm (n = 207)	7.1 (2.16)	8.1 (2.06)	1.00*
Increased risk, 80-87 cm (n = 287)	6.63 (1.85)	7.65 (1.85)	1.02*
Substantially increased risk > 88 cm (n = 819)	5.84 (1.72)	6.71 (1.77)	0.87*

Peak METs reported as mean (standard deviation).
CR, cardiac rehabilitation; METs, metabolic equivalents.
*Change in METs statistically significant at $P < 0.001$ level.

Strengths and limitations

Women are historically underrepresented in CVD and CR research; therefore, an important strength of this study is that data were accrued from a large dataset of women with CVD in

CR. Another strength is that CRF was measured in women in a CR program. Many CR programs do not conduct a pre- and postprogram exercise stress test to evaluate participants' improvements in CRF. It is also noteworthy that only women who opted to enroll in and complete CR were included. As women—and women with obesity, in particular—are less likely to be referred, enroll, and attend CR,[58,59] it is possible that results would be even more pronounced if women who did not enroll or who dropped out early were included.

Although we were able to confirm that patients completed a 12-week supervised exercise program, it would have been ideal to include data on home-exercise activity, which may have varied, especially among women with obesity who might face additional barriers. Furthermore, although this study used tailored exercise prescriptions informed by well-established CR guidelines, the lack of data on participation in nonaerobic or high-intensity modalities, such as resistance training or high-intensity interval training (HIIT), may limit the generalizability of findings to programs emphasizing these approaches. Although this study employed symptom-limited exercise testing that adhered to the American College of Sports Medicine (ACSM) guidelines protocols under the supervision of a highly trained physicians and exercise physiologists, unmeasured subjective influences may still exist. For example, clinician perceptions of a patient's fitness or risk could subtly influence test termination points, as noted in previous research.[22] Another limitation is the absence of data linking short-term improvements in CRF achieved during the 12-week program to long-term clinical outcomes such as readmissions, revascularizations, cardiac events, or mortality specifically in women. Observational data from the TCR database confirm that CRF is a strong predictor of mortality and a key mechanism linking CR attendance to survival in the broader cohort.[20,60] Future research should explore whether these findings hold true for women and determine the minimal clinically important increase in CRF across BMI categories.

Unfortunately, 798 women were excluded because of missing weight measurements; it is not known why these data were missing. These participants had statistically higher ($P < 0.001$) baseline peak MET values, and we do not know how their inclusion may have affected our findings. Finally, the interpretations are limited by lack of sociodemographic data including ethnicity, socioeconomic status, education level, employment, mental health, and exercise capacity. Future researchers could consider collecting additional data on participant characteristics, exercise behaviour, and women's perceptions of barriers to achieving optimal CRF during CR.

Conclusions

A 12-week exercise-based CR program significantly increased CRF in women classified as normal or overweight by BMI. Conversely, change in peak METs was not statistically significant in women classified as obese. Waist circumference categories did not predict degree of improvement in CRF. Identifying characteristics of women who are predisposed to suboptimal improvements in CR may assist in the development of targeted, sex and gender-informed strategies to support optimizing CRF. Further research is needed to evaluate options for targeted support to achieve clinically important improvements in CRF in all women and especially in women with BMI $\geq$ 30.0 kg/m^2 participating in CR.

Ethics Statement

This research was conducted in accordance with the ethical guidelines of the University of Calgary's Conjoint Faculties Research Ethics Board (CFREB) and complies with the ethical principles outlined in the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2).

Patient Consent

This study was approved by the institutional review board (IRB) as a retrospective study using deidentified data; therefore, the IRB did not require consent from the patients. The authors confirm that patient consent is not applicable to this article.

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