Obesity Negatively Impacts Aerobic Capacity Improvements Both Acutely and 1-Year Following Cardiac Rehabilitation

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Cardiac rehabilitation (CR) produces a host of health benefits related to modifiable cardiovascular risk factors. The purpose of the present investigation was to determine the influence of body weight, assessed through BMI, on acute and long-term improvements in aerobic capacity following completion of CR. Three thousand nine hundred and ninety seven subjects with coronary artery disease (CAD) participated in a 12-week multidisciplinary CR program. Subjects underwent an exercise test to determine peak estimated metabolic equivalents (eMETs) and BMI assessment at baseline, immediately following CR completion and at 1-year follow-up. Normal weight subjects at 1-year follow-up demonstrated the greatest improvement in aerobic fitness and best retention of those gains (gain in peak METs: 0.95 ± 1.1, $P < 0.001$). Although the improvement was significant ($P < 0.001$), subjects who were initially classified as obese had the lowest aerobic capacity and poorest retention in CR fitness gains at 1-year follow-up (gain in peak eMETs: 0.69 ± 1.2). Subjects initially classified as overweight by BMI had a peak eMET improvement that was also significantly better ($P < 0.05$) than obese subjects at 1-year follow-up (gain in peak eMETs: 0.82 ± 1.1). Significant fitness gains, one of the primary beneficial outcomes of CR, can be obtained by all subjects irrespective of BMI classification. However, obese patients have poorer baseline fitness and are more likely to "give back" fitness gains in the long term. Obese CAD patients may therefore benefit from additional interventions to enhance the positive adaptations facilitated by CR.

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INTRODUCTION

Improving one's modifiable cardiovascular risk profile is of paramount importance in both primary and secondary prevention settings. Cardiac rehabilitation (CR) produces a host of health benefits related to modifiable cardiovascular risk, perhaps most notable is the significant improvement in aerobic capacity (1–4). The improvement in aerobic capacity is particularly important given the currently available wealth of literature demonstrating a higher fitness level is consistently associated with improved prognosis irrespective of other clinical characteristics (5–7). Given the positive impact CR has on numerous health metrics, it is not surprising there is a well-documented and significant reduction in mortality following participation in this structured lifestyle modification program (1,2).

While the benefits of CR on modifiable cardiovascular risk factors are numerous, amelioration of certain negative characteristics remains elusive. Of particular concern, most patients participating in traditional multidisciplinary CR program fail to lose a significant amount of body weight (8,9). This is an important issue given the majority of patients entering CR are either overweight or obese (9), a fact recognized by current CR guidelines that indicate weight loss should be a primary treatment objective (10).

Given the negative effects of excess body weight on functional capacity and the ability to exercise (11), it is reasonable to posit that aerobic capacity improvements typically gained through CR may be negatively impacted both in the short and long term in patients who are overweight and particularly obese. To our knowledge, this issue has not been previously examined in a comprehensive fashion (i.e., long-term follow-up). The purpose of the present investigation was to determine the influence of body weight, assessed through BMI, on acute and long-term improvements in aerobic capacity following completion of CR. We hypothesize subjects with a BMI classification of *obese* will have a lower aerobic capacity improvement immediately following a 12-week multidisciplinary CR program as well as at 1-year follow-up.

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METHODS AND PROCEDURES

Three thousand nine hundred and ninety seven subjects with coronary artery disease (CAD) participated in a 12-week multidisciplinary CR program (from 1996 to 2010) and additionally returned for reassessment 1-year post-completion. Data used from this analysis was captured in a prospectively constructed clinical database that includes records on all subjects who attend the CR program. Information on additional clinical covariates was obtained from the Alberta Provincial Project for Outcomes Assessment in Coronary Heart disease (APPROACH) database, which collects information on all subjects undergoing coronary catheterization in the Province of Alberta. This project was approved by the local institutional review board in Calgary, Alberta, Canada.

Evaluation procedures

Key clinical characteristics with respect to cardiovascular risk profile were ascertained immediately before CR initiation. Symptom-limited exercise treadmill testing was performed immediately before CR, immediately after CR completion, and at 1-year follow-up post-CR. The peak estimated metabolic equivalent (eMET) value was calculated from treadmill speed and grade during the final stage of the exercise protocol using an established equation (12). BMI was recorded at baseline, immediately following CR and at 1-year follow-up. Subjects were categorized into subgroups according to standard BMI criteria for normal weight (18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2), and obesity (≥30 kg/m^2) (13). During the exercise tests immediately after CR completion and at 1-year follow-up post-CR, subjects also reported the number of times they participated in a structured exercise program per week and the duration of each session at target heart rate, which was used to generate exercise volume in total hours per week. The proportion of offered exercise sessions that subjects attended was also recorded.

Cardiac rehabilitation

Subjects took part in a 12-week supervised exercise program, two times per week, and were encouraged to engage in two to three exercise sessions on their own. The patients were provided a target heart rate and associated eMET level. The 1-h CR sessions were supervised directly by exercise specialists and registered nurses who assisted the patient in safely attaining their appropriate exercise intensity. Exercise intensity and volume were dependent on baseline exercise test results as well as patient exercise and medical history. Following aerobic training, a stretching and resistance training session was offered two times per week (i.e., one stretching session and one resistance training session). In addition, patients voluntarily attended individual counseling appointments with a registered dietitian, registered social worker and/or psychologist. A variety of heart smart education classes were also made available during the same time period.

Statistical analysis

Statistical analysis was performed using SPSS 19.0 (SPSS, Chicago, IL). Continuous data is reported as mean and SD and categorical data is reported as percentages. The χ^2-test assessed differences in key baseline categorical data according to BMI classification. One-way analysis of variance (ANOVA) was used to assess differences in key continuous variables at CR entry according to baseline BMI class. The one-way ANOVA was also used to assess differences in reported weekly exercise volume according to baseline BMI class and change in peak eMET level from baseline to 1-year follow-up in male and female subjects separately according to baseline BMI class. Tukey's honestly significant difference test was used to assess statistical significance when differences amongst BMI subgroups were detected by the one-way ANOVA. A mixed model two-way ANOVA assessed differences in peak eMET level at each of the three exercise tests (within subject factors) according to baseline BMI class (between subject factors). Differences in BMI at the three exercise assessments, according to the baseline BMI classification was also assessed by the mixed model two-way ANOVA. Paired *t*-testing was used to assess change in peak eMET level from baseline to 1-year follow-up in subjects who were initially classified as obese and either maintained or decreased their initial BMI classification. Pearson's correlation and scatter plots were used to assess the relationship between change in BMI and change in peak eMET level from baseline to both immediately post CR and 1-year follow-up. Multiple binary logistic regression was used to determine if age (</≥65 years), sex (male/female) and/or low baseline fitness level (≤/> 5 eMETs) were predictive of an increase in BMI class (i.e., weight gain/negative outcome) at 1-year follow-up. All statistical tests with a P value < 0.05 were considered significant.

RESULTS

Baseline characteristics for subjects according to baseline BMI class are listed in **Table 1**. Subjects who were initially classified as obese were significantly younger compared to both overweight and normal weight subjects. The percentage of male subjects was significantly higher in the overweight and obese groups. Overall, obese subjects presented with a poorer cardiovascular risk profile in several respects, including a higher prevalence of hypertension, hyperlipidemia, diabetes, and tobacco use.

Table 2 lists the change in BMI according to classification at baseline. As expected, mean BMI was significantly different among normal weight, overweight, and obese groups at each of the assessment points. Normal weight subjects at baseline demonstrated no change in BMI at 12 weeks and a significant increase at 1-year follow-up. Overweight subjects at baseline demonstrated a significant decrease in BMI at 12 weeks and a significant increase at 1-year follow-up. Obese subjects at baseline also demonstrated a significant decrease at 12 weeks while 1-year follow-up BMI was comparable to baseline.

Immediately following CR, 89% of the subjects did not change BMI classification while 7% decreased to a lower class and 4% increased to a higher class. Compared to baseline data, 83% of the subjects had the same BMI classification at 1-year follow-up whereas 7% decreased to a lower class and 10% increased to a higher class. The distribution of subjects in the BMI classes was significantly different from the immediate

Table 1 Baseline characteristics

	Normal weight (n = 1,075)	Overweight (n = 1,929)	Obese (n = 993)	P value
Age (mean)	61.4 ± 10.6	60.4 ± 10.5	57.8[a]	<0.001
Male (%)	72.7[b]	81.2	79.4	0.003
Diabetic (%)	12.7	11.9	23.0[a]	<0.0001
Hypertensive (%)	48.8[c]	56.2[c]	66.5[c]	<0.0001
Hyperlipidemia (%)	63.9[b]	71.3	73.9	<0.001
Current smokers (%)	18.7	19.8	24.3[a]	0.003
Congestive heart failure (%)	8.3	7.6	8.1	0.798
Renal failure (%)	>1.0	1.0	1.2	0.557
COPD (%)	9.7	9.1	11.0	0.277

COPD, chronic obstructive pulmonary disease.
[a]Obese subjects significantly different than overweight and normal weight subjects. [b]Normal weight subjects significantly different than overweight and obese subjects. [c]All three groups significantly different.

post-CR assessment to 1-year follow-up due to a lower percentage of subjects maintaining baseline BMI class and a higher percentage shifting to a higher BMI class.

Table 3 lists peak eMET level at each assessment as well as the change in peak eMETs immediately following CR and at 1-year follow-up according to baseline BMI class. The obese group demonstrated a significantly lower peak eMET level at all three assessments. However, all three groups demonstrated a significant increase in peak eMETs immediately after CR as well as at 1-year follow-up compared to baseline. Mean peak eMET improvement was significantly greater in normal weight subjects compared to overweight and obese subjects immediately following CR. Normal weight subjects at 1-year follow-up demonstrated the greatest improvement in aerobic fitness and best retention of those gains at 1-year follow-up, which was significantly greater than overweight and obese subjects. The peak eMET improvement in subjects initially classified as overweight by BMI was significantly better than obese subjects at 1-year follow-up.

At the start of CR, obese subjects reported a considerably lower volume of exercise time in comparison to those who were normal or overweight (Table 3). Immediately following CR, self-reported weekly exercise volume was not different across weight class, and, in fact, those who were obese had the greatest increase in exercise volume over baseline. However, at 1-year follow-up, self-reported weekly exercise decreased vs. end of program completion, such that there were no gains relative to baseline regardless of starting weight class, a difference which was the same across all weight groups. Baseline weight status was not associated with the proportion of exercise sessions attended: normal weight, obese, and overweight subjects all attended the same proportion of sessions while enrolled in CR (72.0, 71.5 and 70.3%, respectively; $P = 0.7420$).

When assessing male ($n = 3,288$) and female ($n = 709$) subjects separately, similar trends in retention of aerobic capacity gains were apparent in both subgroups with some sex-based differences. Change in peak eMET level from baseline to 1-year follow-up in male subjects initially classified as normal weight, overweight or obese was 0.98 (±1.15), 0.84 (±1.10), and 0.72 (±1.16) eMETs, respectively. In male subjects, retention of fitness gains was significantly different across the three

Table 2 Summary of baseline BMI and changes at 12 weeks at 1-year post cardiac rehabilitation according to baseline BMI

	Normal weight[b]	Overweight[c]	Obese[d]
	n = 1,075 (BMI: 18.5–24.9 kg/m²)	*n* = 1,929 (BMI: 25.0–29.9 kg/m²)	*n* = 993 (BMI: ≥30 kg/m²)
Baseline BMI (kg/m²)[a]	23.1 ± 1.4	27.3 ± 1.3	33.3 ± 3.2
BMI at 12 weeks (kg/m²)[a]	23.2 ± 1.5	27.1 ± 1.6	32.9 ± 3.4
BMI at 1-year follow-up (kg/m²)[a]	23.6 ± 1.8	27.5 ± 2.0	33.4 ± 3.7
Change in BMI: baseline to 12 weeks (kg/m²)[a]	0.02 ± 0.8	–0.17 ± 0.9	–0.37 ± 1.3
Change in BMI: baseline to 1 year (kg/m²)[a]	0.42 ± 1.2	0.23 ± 1.5	0.04 ± 2.0

[a]All three groups significantly different ($P < 0.01$). [b]Normal weight group: no change from baseline to 12 weeks ($P = 0.60$), significant increase from baseline to 1 year ($P < 0.001$). [c]Overweight group: significant decrease from baseline to 12 weeks ($P < 0.001$), significant increase from baseline to 1 year ($P < 0.001$). [d]Obese group: significant decrease from baseline to 12 weeks ($P < 0.001$), no change from baseline to 1 year ($P = 0.52$).

Table 3 Summary of baseline exercise capacity, exercise time and changes at 12 weeks at 1-year post cardiac rehabilitation according to baseline BMI

	Normal weight[d]	Overweight[d]	Obese[d]
	n = 1,075 (BMI: 18.5–24.9 kg/m²)	*n* = 1,929 (BMI: 25.0–29.9 kg/m²)	*n* = 993 (BMI: ≥30 kg/m²)
Baseline peak eMETs[a]	8.3 ± 2.0	8.2 ± 1.9	7.4 ± 1.9
Peak eMETs at 12 weeks[a]	9.3 ± 2.0	9.1 ± 1.9	8.3 ± 1.9
Peak eMETs at 1-year follow-up[b]	9.2 ± 2.2	9.0 ± 2.1	8.1 ± 2.0
Change in peak eMETs: baseline to 12 weeks[c]	1.00 ± 0.9	0.92 ± 0.9	0.87 ± 0.9
Change in peak eMETs: baseline to 1 year[b]	0.95 ± 1.1	0.82 ± 1.1	0.69 ± 1.2
Time spent exercising at prescribed heart rate at baseline (min)[a]	153.3 ± 131.1	149.8 ± 128.2	123.5 ± 122.9
Time spent exercising at prescribed heart rate at 12 weeks (min)[e]	164.0 ± 92.3	168.6 ± 99.2	163.0 ± 94.8
Time spent exercising at prescribed heart rate at 52 weeks (min)[a]	150.0 ± 115.4	142.8 ± 116.3	121.2 ± 110.2
Change in exercise time: baseline to 12 weeks (min)[f]	10.2 ± 128.4	19.9 ± 130.3	39.3 ± 126.5
Change in exercise time: baseline to 52 weeks (min)[g]	–3.1 ± 142.2	–7.7 ± 142.9	–2.1 ± 142.8

eMETs; estimated metabolic equivalents.
[a]Obese group significantly less than normal weight and overweight groups ($P < 0.001$). [b]All three groups significantly different ($P < 0.05$). [c]Normal weight group significantly greater than overweight and obese groups ($P < 0.05$). [d]Significant increase in peak MET level following CR (12 weeks and 1 year) compared to baseline for all BMI groups ($P < 0.001$). [e]No difference between groups ($P = 0.2275$). [f]All three groups different ($P = 0.0016$). [g]No difference between groups ($P = 0.7302$).

BMI groups and greatest for those initially classified as normal weight ($P < 0.05$). Change in peak eMET level from baseline to 1-year follow-up in female subjects initially classified as normal weight, overweight or obese was 0.87 (±1.08), 0.62 (±1.13), and 0.55 (±1.12) eMETs, respectively. The retention of fitness gains in female subjects initially classified as normal weight was significantly greater than those initially classified as overweight or obese ($P < 0.05$).

At 1-year follow-up, 13% of the subjects initially classified as obese dropped to a lower BMI class (i.e., overweight or normal weight). The mean peak eMET improvement form baseline to 1-year follow-up was significantly greater for subjects who decreased to a lower BMI class (1.2 ± 1.3 vs. 0.61 ± 1.1 eMETs, $P < 0.001$). There was a correlation demonstrated between BMI and eMETs change from start to completion of CR, with similar correlations across weight classes: the more weight loss, the greater the improvement in eMETs (**Figure 1**). Considering 1-year data, the correlation between BMI loss and eMETs gained was strengthened, with the strongest correlation in subjects who started CR obese (**Figure 2**).

Using multiple binary logistic regression, female subjects were significantly more likely (odds ratio 1.4 (95% confidence interval: 1.1–1.8), $P < 0.004$) to gain weight and increase their BMI class at 1-year follow-up compared to males. Low fitness level and age were not significant predictors of an increase in BMI class ($\chi^2 \leq 2.5$, $P > 0.10$).

DISCUSSION

Consistent with previous findings (9), our results indicate a majority of patients entering CR present with excess body mass. However, regardless of baseline BMI, all subjects completing CR demonstrated considerable gains in fitness over the course of the 12-week program. Disappointingly, these gains were not consistently maintained at 1 year in subjects with excess body mass, particularly those classified as obese at baseline. Given the importance of cardiovascular fitness in protecting against recurrent events and death, this is an important finding with the increasing prevalence of obesity in subjects with CAD (14).

The majority of the cohort included in the present investigation demonstrated no change in BMI class immediately following CR participation, indicating substantial weight loss was not a primary benefit of this 12-week comprehensive lifestyle modification program. This latter finding is also consistent with previous research that supports the premise that modern day approaches commonly employed in CR are largely ineffective for weight loss (15,16). Perhaps a more novel and troubling finding is that mean BMI and the percentage of subjects progressing to a higher BMI class increased at 1-year follow-up, particularly in women. While the absolute change in BMI is small, it may be expected that subjects are likely to continue to increase in weight over the long term. These findings would indicate there is a greater likelihood of weight gain in the long term once patients complete a structured CR program and are expected to be independently compliant with lifestyle modification. This observation is consistent with other studies demonstrating substantial weight gain is common once a patient is diagnosed with CAD (17). Additionally, it appears that patients who experience weight loss during CR, even those initially classified as having a normal BMI, have an improved prognosis

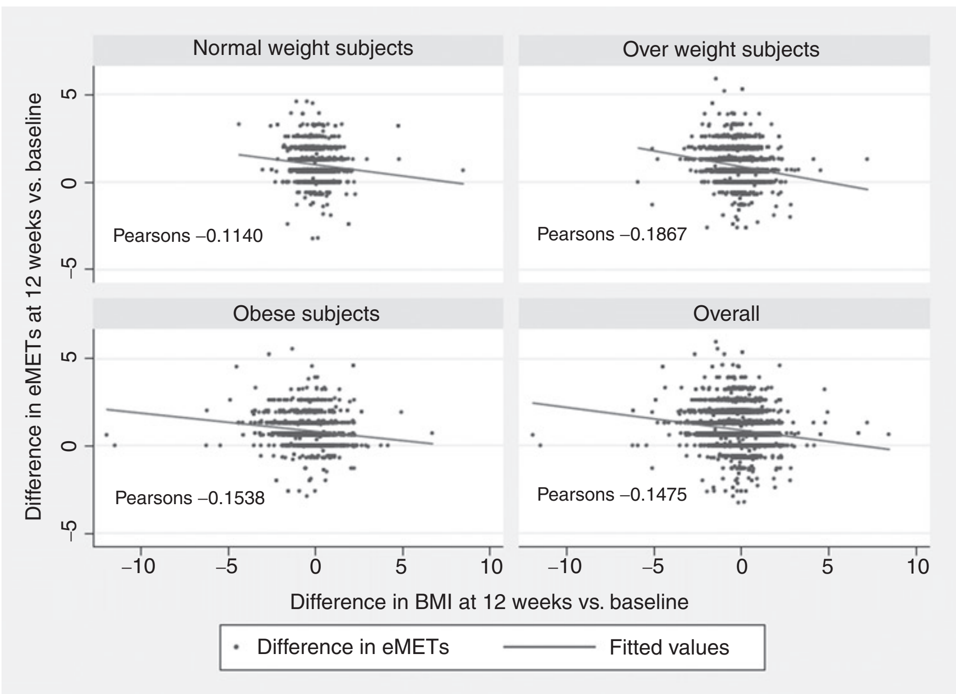

Figure 1 Correlation between change in peak eMET level and BMI from baseline to 12-week follow-up according to initial BMI classification. eMET, estimated metabolic equivalent. All correlations $P < 0.001$.

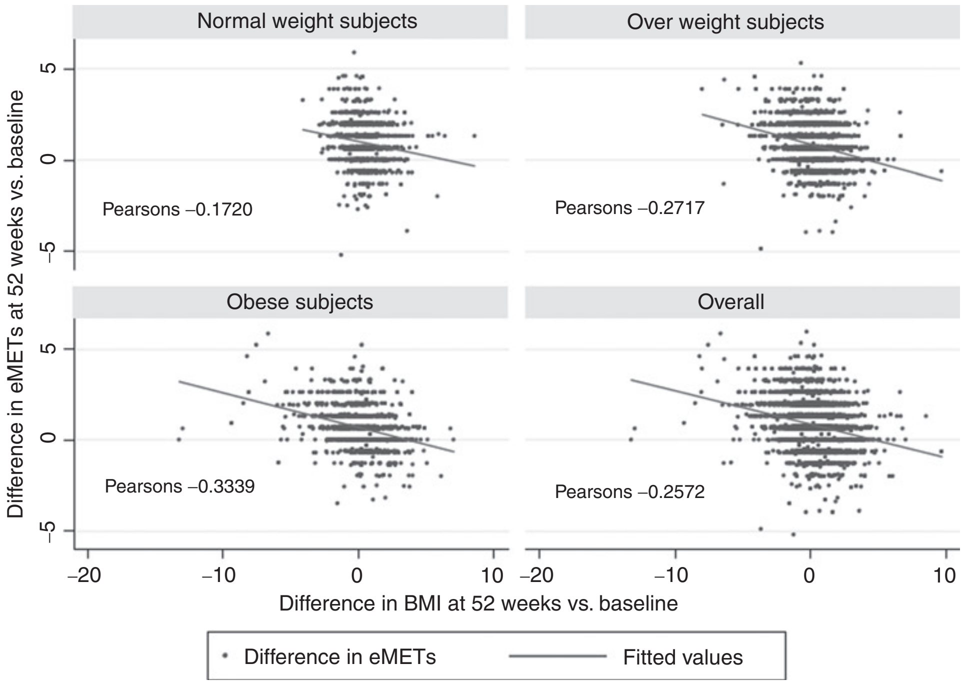

Figure 2 Correlation between change in peak eMET level and BMI from baseline to 1-year follow-up according to initial BMI classification. eMET, estimated metabolic equivalent. All correlations $P < 0.001$.

compared to those who did not lose weight (18). Thus, efforts are required to facilitate meaningful weight loss during CR and at a minimum maintain these improvements in the long term following program completion. Future research should also be directed toward identifying patient characteristics that may predict a higher likelihood for long-term weight gain in order to focus greater attention on high-risk groups. There is emerging evidence to indicate meaningful weight loss is possible through individualized CR programming directed toward higher caloric expenditure and a negative caloric balance (8,19,20). Efforts to translate this evidence into clinical practice should continue, with future research focusing on strategies to ensure maintenance of weight loss achieved through CR in the long-term. Also of note, the current study found weight gain is greatest in subjects who have a *normal* BMI to start, perhaps indicating that weight maintenance education needs to be part of CR regardless of starting weight.

Previous investigations have found that, in general, preservation of improved risk factor profile following CR is apparent at 12–18 month follow-up (21–23). While the present study indicates improvements in aerobic capacity following CR are possible both in the short and long term irrespective of BMI status, obese subjects start at a lower aerobic capacity and realize smaller fitness gains immediately following CR, a finding consistent with previous investigations (24,25). A particularly novel finding of the current investigation is that obese subjects are more likely to lose gains in fitness over the long term. These trends were consistent for both male and female patients initially classified as obese. This is particularly disconcerting given the wealth of evidence demonstrating greater improvements in aerobic fitness equate to a more favorable prognostic profile, and that obesity remains associated with a poor cardiac risk profile even in very fit subjects (26,27). In addition, given the normally expected age-related decline in aerobic capacity, the fact that obese subjects were significantly younger compared to normal weight and overweight subjects in the current study is another reason for concern over the long-term prognosis. Our data on self-reported physical activity immediately after CR and at 1-year follow-up may serve as a plausible mechanism for the poorer retention of fitness gains and perhaps, an area for intervention. Immediately following CR, the self-reported volume of exercise was similar in normal weight, overweight and obese subjects, demonstrating that obese subjects respond well while under the direction of a CR program: all subjects attended the same proportion of exercise sessions, and exercise time equalized over weight categories by the time of CR completion. However, at 1-year follow-up, self-reported physical activity was significantly lower in subjects initially classified as obese. Additionally, other authors have shown that for similar amounts of physical activity obese subjects achieve lower levels of fitness than normal weight subjects (28). Thus, it would appear the risk of poor exercise adherence and loss of CR benefits are greater in subjects who are obese. This has been demonstrated by other authors, who have shown that self-motivation is lower among obese subjects vs. normal weight, demonstrating a potential role for ongoing structured intervention to improve physical activity compliance (11). Therefore, strategies specifically directed toward obese subjects with CAD to help ensure and facilitate lifestyle modification compliance in the long term may be warranted.

Immediately following CR, Lavie and Milani (25) previously demonstrated obese subjects who lost weight demonstrated a significantly greater improvement in aerobic capacity compared to obese subjects who did not lose weight, a finding confirmed in other investigations (29,30). Our findings are consistent in that subjects initially classified as obese who no longer met this criteria (i.e., BMI ≥30 kg/m^2) at 1-year follow-up demonstrated a significantly greater peak eMET improvement compared to subjects who did not significantly reduce their body mass. The results of the present study, in conjunction with previous findings, highlight the importance of weight loss for both acute and long-term fitness gains following CR. There may, however, be some confounding evidence in this regard: there is considerable evidence that the addition of exercise training to a weight loss program improves weight maintenance (31). Thus, it is possible that subjects who maintain weight loss do so because of maintenance of physical activity, rather than vice versa. Regardless, there is a subset of obese subjects who demonstrate particular improvements through the course of a CR program, and what motivates them to achieve success and maintain it is of great interest. Evidence from weight loss trials demonstrates that longer interventions are necessary to make lifestyle changes (and weight loss) permanent, as the efficacy of short-term interventions is time limited (32).

Numerous investigations have previously demonstrated that patients with CAD who are classified as obese by BMI present with a more favorable prognosis compared to those in the normal weight BMI range (33). This phenomenon has been termed the "obesity paradox" and has raised questions over appropriate body mass status for the CAD population. It is clear that excess body weight increases the risk for the development of CAD and weight loss efforts are essential in the primary prevention setting (34). A commonality of studies supporting the obesity paradox in CAD is there was no distinction between unintentional and intentional weight loss. Ideally, CR induces intentional weight loss, which has been shown to produce numerous significant improvements in cardiovascular risk profile (35) and survival (18). Moreover, it appears the prognostic benefit gained through improved aerobic capacity supersedes any potential benefit derived from excess body weight in patients with CAD (36–38). The results of the current and previous (25) investigations indicate greater gains in aerobic capacity are realized in obese patients who lose a significant amount of weight through CR. Given the important prognostic benefit of a high aerobic capacity in conjunction with no indication that intentional weight loss is detrimental, CR programs should strive to improve weight-loss strategies.

There are of course limitations to this study that must be noted. First, while BMI has certainly proven valuable as a measure of body habitus, other more specific measures of adiposity and their relationship to fitness gains may provide additional insight. Unfortunately, we did not have percent-body fat data collected in subjects included in the current analysis, and hence are unable to detect improvements in body composition which may be significant (39). Future investigations should be conducted to compare the ability of BMI and other measures of body habitus to reflect fitness gains in patients participating in CR. In addition, aerobic capacity was estimated from treadmill speed and grade as opposed to directly measured by ventilatory expired gases, introducing the likelihood of some error in our quantification of fitness level. Even so, numerous investigations have demonstrated the clinical utility of measuring aerobic capacity in this fashion (7). Inclusion of subjects in the current study was dependent upon return for their 1-year follow-up assessment, introducing the potential for selection bias. It is plausible to speculate that subjects failing to return for their 1-year follow-up would have different retention of fitness characteristics irrespective of BMI classification. Therefore, the results of the present study must be interpreted with some caution in the sense that they may not reflect fitness retention patterns of the entire CAD population participating in CR. Even so, given the fact that our findings regarding the interaction between fitness gains and BMI are consistent with previous investigations lends validity to the supposition that obese patients, reflected by BMI, enter CR with a lower fitness level, have diminished fitness gains immediately following CR, and are more likely to lose fitness gains in the long term.

In conclusion, the results of the current study support the broad application of CR to patients with CAD irrespective of baseline status. Specifically, significant fitness gains, one of the primary beneficial outcomes of CR, can be obtained by all subjects irrespective of baseline BMI classification. However, obese patients present with a lower baseline fitness level, have an attenuated gain in aerobic capacity immediately following CR and are more likely to "give back" those fitness gains in the long term. Though currently infrequent, obese patients who are able to lose a significant amount of weight may not suffer the same fate. Therefore, obese patients with CAD who enter CR may benefit from additional interventions to facilitate weight loss and improve exercise compliance with the hopes of improving fitness gains and preventing the loss of positive adaptations facilitated by CR in the long term.

DISCLOSURE

The authors declared no conflict of interest.
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