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Predictors of Cardiorespiratory Fitness Improvements With Cardiac Rehabilitation: Lower Baseline Fitness With the Most to Gain, Gains the Most

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Cardiorespiratory fitness (CRF), measured as peak metabolic equivalents (METs) estimated during a symptom-limited exercise test, is a major independent predictor for all-cause mortality in healthy individuals and patients with coronary artery disease (CAD).^{1,2} Comprehensive cardiac rehabilitation (CR)—consisting of medical evaluation, exercise training, cardiac risk-factor modification, nutrition counseling, and stress management—is an effective therapeutic intervention to reduce mortality, morbidity, and hospitalization in patients with CAD.³ The success of CR is due, in part, to an exercise-mediated improvement in CRF.^{4–7} Indeed, each 1-MET increase in CRF is associated with a 25% reduction in mortality.⁶

Typically, the average increase in CRF with CR is 1.6 METs;⁷ however, some previous studies report minimal or no significant improvement after CR.^{8,9} Accordingly, identifying the determinants of the improvement in CRF associated with CR participation is of important clinical significance and may assist CR specialists to design and implement strategies to improve CRF optimally with this intervention.

In this issue of *Canadian Journal of Cardiology*, Laddu et al.¹⁰ fill an important knowledge gap by determining and comparing the predictors of post-CR CRF improvement in patients with clinically stable cardiovascular disease (CVD) who have varying baseline MET levels and prevalence of comorbidity. To achieve this, Laddu et al.¹⁰ conducted a retrospective analysis, using the Alberta Provincial Project for Outcomes Assessment in Coronary Heart Disease (APPROACH) and TotalCardiology rehabilitation databases between 1996 and 2016, of a large, well-defined cohort of 10,732 patients with stable CVD (most commonly CAD; mean age: 60.4 years, 81.8% male, body mass index: 28.5 kg/m²) who completed a 12-week multidisciplinary CR program in Calgary, Alberta, Canada.

To be included in the analysis, patients had to be older than 18 years of age and have completed the 12-week CR program (defined as completion of baseline and 12-week post-

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CR assessment). The CR program consisted of 12 weeks of supervised exercise training with 2 60-minute exercise sessions each week (endurance training and supplemental strength training 1 day per week), and patients were encouraged to participate in an additional 2 to 3 exercise sessions a week on their own. Patients were also offered nutrition, stress management, and smoking-cessation classes. Peak METs were calculated from treadmill speed and grade during the final stage of a Bruce protocol and used to stratify patients based on their baseline exercise test into low (L-Fit, < 5 METs, 9.2% of patients), moderate (M-Fit, 5–8 METs, 44.3% of patients), or high fitness (H-Fit, > 8 METs, 46.4% of patients) subgroups. The primary outcome was 12-week (post-CR completion) METs. Multivariate linear regression models were created to predict peak METs at program completion in the entire cohort and by baseline CRF stratification. All models were adjusted for age, sex, obesity and smoking status, coronary interventions and severity of CVD, comorbidities, and type of program (home vs center program enrolment).

Laddu et al.¹⁰ found that mean baseline METs was the strongest predictor of METs achieved at completion of CR before and after adjusting for sex, demographics, and comorbidities across all fitness groups. This is an important finding, as Martin and colleagues⁶ previously demonstrated that baseline CRF predicted long-term survival in patients with CAD. Laddu et al.¹⁰ also found that the 12-week CR program was effective in improving CRF (overall mean increase: 0.93 METs, 12.4%), with the greatest increase occurring in L-Fit (1.3 METs, 35% increase), followed by M-Fit (1.03 METs, 16% increase), and H-Fit (0.77 METs, 8% increase). The increased peak METs observed among the L-Fit group likely has important clinical significance, given that a 1-MET improvement in CRF has been shown to be associated with a 30% reduction in mortality in patients with CAD who had low fitness before beginning a CR program.⁶ Furthermore, the magnitude of improvement in METs may also have a profound impact on functional independence for L-Fit patients. Specifically, the average baseline CRF for L-fit patients was 27% below the MET level that optimally distinguishes between high and low physical function¹¹ and increased to this threshold level after participation in CR. Accordingly, activities of daily living that require near-maximal effort in L-fit patients (especially those with comorbidities and chronic disease) before participation in CR will be performed at a lower relative percent of their peak MET value after participation in CR.

Laddu et al.¹⁰ also found that advancing age, female sex, current smoking, diabetes, increased body mass index, and home program participation were all significant negative predictors of peak METs achieved following 12 weeks of CR. Finally, in L-Fit patients, the presence of diabetes, chronic obstructive pulmonary disease, and previous coronary artery bypass graft surgery explained a greater proportion of model variance in post-CR CRF levels than in M-Fit or H-Fit models. Taken together, these findings identify patient and clinical factors that may predispose individuals with CVD to achieve suboptimal improvements in CRF. This knowledge can be used by cardiac rehabilitation specialists to tailor their programs to overcome negative predictors of CRF via risk-factor management or behavioral interventions to ensure optimal improvements in CRF after participation in CR.

There are several limitations to the study by Laddu and colleagues.¹⁰ First, the authors defined CR completion as attending baseline and post-CR assessment at 12 weeks;

therefore, the impact of exercise attendance on changes in CRF overall, and by baseline fitness subgroups, is uncertain. As such, future studies are required to investigate whether the number of CR sessions attended differs by the same patient factors examined by Laddu et al.¹⁰ and whether or not higher attendance and adherence to prescribed exercise intensity (dose-response) confers a greater improvement in CRF.

A second limitation of the study by Laddu et al.¹⁰ is the under-representation of elderly persons (>70 years) and women (16.7% and 18.2% of full cohort, respectively). Importantly, Vonder Muhll et al.¹² reported that CRF improved by 20% in older (mean age: 82 years) patients with CAD after participating in a comprehensive CR program. Moreover, the relative improvement in peak METs was similar between older men and women.¹² A final limitation of the study by Laddu et al.¹⁰ is that the determinants (along the oxygen cascade) responsible for the increase in CRF were not studied. Accordingly, future research should focus on the physiological mechanisms (cardiac, vascular, and skeletal muscle) responsible for the exercise-mediated improvement in CRF and determine if these adaptations differ by baseline fitness, age, gender, and comorbidities. Improved understanding of these mechanisms will allow CR specialists to better individualize exercise programs to obtain optimal improvements in CRF.

In summary, Laddu et al.¹⁰ demonstrate that, across all fitness groups, mean baseline CRF was the strongest predictor of METs achieved at completion of CR. Moreover, the greatest improvement in CRF with CR occurs in L-Fit patients with CVD. This has important clinical significance, as patients with CVD who have the lowest CRF stand to obtain the greatest improvements in mortality and functional independence with completion of CR.

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