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Effects of resistance training combined with moderate-intensity endurance or low-volume high-intensity interval exercise on cardiovascular risk factors in patients with coronary artery disease

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ABSTRACT

Objectives: To determine the effects of resistance training combined with either moderate-intensity endurance or low-volume high-intensity interval training on cardiovascular risk profiles in patients with coronary artery disease.
Design: Factorial repeated-measures study design.
Methods: Nineteen patients were randomized into moderate-intensity endurance ($n = 10$) or high-intensity interval ($n = 9$) groups, and attended 2 supervised exercise sessions a week for 6-months. The first 3-months involved exclusive moderate-intensity endurance or high-intensity interval exercise, after which progressive resistance training was added to both groups for the remaining 3-months. Fitness (VO_2peak), blood pressure and heart rate, lipid profiles and health related quality of life assessments were performed at pretraining, 3 and 6-months training.
Results: VO_2peak increased from pretraining to 3-months in both groups (moderate-intensity endurance: 19.8 ± 7.3 vs. $23.2 \pm 7.4\,ml\,kg^{-1}\,min^{-1}$; high-intensity interval: 21.1 ± 3.3 vs. $26.4 \pm 5.2\,ml\,kg^{-1}\,min^{-1}$, $p < 0.001$) with no further increase at 6-months. Self-evaluated health and high-density lipoprotein were increased following 6-months of moderate-intensity endurance exercise, while all remaining indices were unchanged. Low-volume high-intensity interval exercise did not elicit improvements in lipids or health related quality of life. Blood pressures and heart rates were unchanged with training in both groups.
Conclusions: Findings from our pilot study suggest improvements in fitness occur within the first few months of training in patients with coronary artery disease, after which the addition of resistance training to moderate-intensity endurance and high-intensity interval exercise elicited no further improvements. Given the importance of resistance training in cardiac rehabilitation, additional research is required to determine its effectiveness when combined with high-intensity interval exercise.

1. Introduction

High-intensity interval exercise training (HIIT) has been shown to elicit comparable and/or superior improvements in numerous cardiovascular disease risk factors when compared to the moderate-intensity endurance exercise (MICT) most commonly in use in cardiac rehabilitation.[1–3] The HIIT protocols employed in these studies were matched to MICT in terms of calories expended or volume of exercise. More recently, low-volume HIIT which is neither isocaloric or isovolumetric, has been shown to elicit beneficial physiological adaptations in patients with coronary artery disease (CAD).[4] Additionally, both HIIT and low-volume HIIT have no reported adverse events, and similar program adherence as MICT,[1,2,4] therefore encouraging the use of HIIT for aerobic exercise prescription in the cardiac rehabilitation setting.

Current cardiac rehabilitation guidelines recommend the inclusion of a standardized resistance-training program.[5,6] A recent meta-analysis of exercise training programs in patients with CAD

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revealed the addition of resistance exercise training to MICT led to superior improvements in body composition, muscle strength, peak work capacity, and a trend for greater increases in VO_2peak.[7] Similar to HIIT, resistance training has not been shown to compromise patient safety or program adherence.[7] Isovolumetric HIIT combined with resistance training has been shown to improve VO_2peak in patients with CAD[2,8]; however the effectiveness of low-volume HIIT combined with resistance training has yet to be determined. The purpose of this pilot study was twofold: (1) to compare the effects of 3-months of MICT versus low-volume HIIT on cardiovascular risk factors in patients with CAD, and (2) to compare whether the addition of resistance training to both protocols for an additional 3-months elicits any further gains in the measured outcomes. The primary outcome measure was VO_2peak, while secondary outcomes included supine heart rate and blood pressure, lipid profiles, and health related quality of life (HRQL). Based on the previous interval and resistance literature,[2,4,8] we hypothesized that low-volume HIIT plus resistance and MICT plus resistance would result in comparable improvements in cardiovascular disease risk factors.

2. Methods

Eligible patients were recruited on admission to a phase II cardiac rehabilitation outpatient program at the Cardiac Health and Rehabilitation Centre at the Hamilton Health Sciences General Site (Hamilton, Ontario). Inclusion criteria included a recent (<3 months) CAD event, which was defined as the patient having at least one of the following: myocardial infarction, percutaenous coronary intervention or coronary artery bypass graft; angiographically documented stenosis ≥50% in at least one major coronary artery; positive exercise stress test determined by symptoms of chest discomfort accompanied by electrocardiographic (ECG) changes of >1 mm horizontal or down sloping ST-segment depression, or a positive nuclear scan. Exclusion criteria have been previously published.[9] Twenty-eight patients (2 females) were recruited to participate; however, 8 males and 1 female dropped out of the study due to reasons unrelated to the exercise interventions. Therefore 19 patients completed the study. The study protocol was approved by the Hamilton Health Sciences/Faculty of Health Sciences Research Ethics Board, conforming to the Declaration of Helsinki, and written informed consent was obtained from patients prior to participation.

This study employed a factorial repeated-measures design. Patients underwent 2 testing sessions each at baseline (pretraining), 3 and 6-months training. The first testing session involved a lipid panel and medically supervised exercise stress test. The second visit involved measurements of resting heart rate, blood pressure, and HRQL. Prior to each testing session, patients were instructed to fast for at least 12 h, to abstain from caffeine and alcohol consumption for 12 h and exercise for 24 h, and to take all medications and vitamins as usual. All testing was performed in a temperature-controlled room ($22.7 \pm 1.3^{\circ}$ C). Following the pretraining assessments, patients were randomized into either MICT ($n = 10$, 1 female) or HIIT ($n = 9$).

Venous blood draws were taken, and serum total cholesterol, triglyceride, high-density lipoprotein, and low-density lipoprotein were measured using standard procedures at laboratories affiliated with the rehabilitation center.

Patients performed a medically supervised graded exercise test to volitional fatigue on a cycle ergometer (Ergoline, Bitz, Germany). Following an unloaded warm-up, patients cycled at 100 kpm for 1-min, after which workload was increased by 100 kpm every min until volitional fatigue. Heart rate was assessed throughout the test using a 12-lead ECG (MAC 5500; General Electric, Freiburg, Germany). Oxygen uptake was determined at peak (VO_2peak) from breath-by-breath expired gas samples analyzed using a semi-automated metabolic cart (Vmax 229; SensorMedics Corporation, Yorba Linda, CA, USA). No patients satisfied the maximal oxygen uptake (VO_2max) criteria of a plateau in oxygen uptake with increased workload and a respiratory exchange ratio ≥1.15.[10]

Heart rate and brachial artery blood pressure were recorded in the supine position following 10 min of rest. Heart rate was measured using a single-lead (CC5) ECG (model ML 132; ADInstruments Inc., Colorado Springs, CO, USA), while continuous brachial artery blood pressures were recorded using a non-invasive hemodynamic monitor (Nexfin, BMEYE, Amsterdam, The Netherlands). Heart rate and blood pressure values are reported as the average from a 5-min sample.

HRQL was measured by the Short Form-36,[11] which is composed of 8 subscales (physical functioning, general health, role-physical, bodily pain, mental health, role-emotional, vitality, and social functioning), two summary scores (mental health and physical health), and a single-item assessing self-evaluated health transition.

Patients attended 2 supervised exercise sessions per week for 6 months. Each session involved a 10-min standardized warm-up and cool-down consisting of light aerobic exercise and dynamic stretching. Heart rate was monitored throughout each exercise sessions using a Polar heart rate monitor (RS300X; Lachine, QC, Canada). Additionally, the total external work per session (kJ) was calculated by multiplying the duration of aerobic exercise by the intensity in watts. Both MICT and low-volume HIIT were performed on a cycle ergometer (Ergomedic 828 E; Monark Exercise AB, Vansbro, Sweden). The first 3 months of training solely consisted of MICT or low-volume HIIT. The MICT protocol was based on the Canadian Association of Cardiac Rehabilitation guidelines,[6] and involved continuous cycling at 57% (range 51–65%) of their pretraining peak power output (PPO_{pre}). Patients progressed from 30 min for month 1, to 40 min from month 2, to 50 min from month 3. The low-volume HIIT protocol was based on previous research in a middle-aged clinical population[12] and involved 10, 1-min intervals at 85% of PPO_{pre} (range 75–93%), separated by 1-min intervals at 10% of PPO_{pre}. Exercise progressions included increasing the intensity every month to continue to elicit heart rates associated with their initial PPO_{pre}. Therefore, patients were training at 100% PPO_{pre} for month 2 and 108% PPO_{pre} for month 3. During the final 3 months, the HIIT group trained at 121% (range 100–152%) of PPO_{pre}, while the MICT group trained at 78% (range 60–91%) of PPO_{pre}.

Cardiac rehabilitation guidelines recommend adding resistance training following an initial period of aerobic training.[5,6] Therefore, following the first 3 months of MICT and HIIT, standardized resistance training programs were added to both groups after the MICT or HIIT bouts for the remaining 3 months. Patients performed 2 sets of 10–12 reps of various upper body and lower body resistance exercises. The amount of weight was determined using the Borg ratings of perceived exertion scale as enough weight to elicit a score of 11–15, or "somewhat hard". The amount of weight was increased periodically over the 3 months to ensure patients continued to work at a score of 11–15. Possible exercises included leg press, leg extension, calf raises, biceps and triceps curls, chest press, seated row, and abdominal crunches.

Statistical analyses were performed using Statistical Package for Social Science software (version 20.0; IBM Corporation, Armonk, NY, USA). All data were assessed for normal distribution using Shapiro–Wilk tests. Between-group differences in characteristics, pretraining indices, and training data were compared using independent *t*-tests for normally distributed data, and Mann–Whitney *U* tests for non-normally distributed and categorical data. The effects of training on primary and secondary outcomes were performed for MICT and HIIT groups using repeated measures analyses of variance and Friedman's tests for normally and non-normally distributed data, respectively. Main effects were tested

Table 1
Patient characteristics.

Variable	END (n = 10)	HIT (n = 9)	p-Value
Age (years)	66 ± 8	63 ± 8	0.372
Height (m)	1.70 ± 0.08	1.76 ± 0.06	0.080
Time since CAD event (days)	163 ± 64	157 ± 52	0.829
CAD criteria (number)			
MI	6	6	0.770
PCI	7	4	0.273
CABG	3	4	0.526
Medication classification (number)			
ACE inhibitors	6	7	0.418
Anti-Platelets	10	9	0.999
β-Blockers	7	7	0.708
Calcium channel blockers	1	2	0.478
Statins	8	9	0.167

Values are mean ± SD, unless otherwise stated. ACE, angiotensin-converting enzyme; CABG, coronary artery bypass graft; CAD, coronary artery disease; MI, myocardial infarction; PCI, percutaneous coronary intervention.

using Fisher's least significant difference tests. To determine if the magnitude of change was greater in one group, delta scores were calculated for significant indices, and compared between MICT and HIIT using independent t-tests. Data are presented as mean ± SD, with $p < 0.05$ considered statistically significant.

During the course of the study, 2 males had changes in their cardioselective β-blockers; therefore they were excluded from the heart rate analyses (END = 9; HIT = 8). One female and 1 male in the END group and 1 male in the HIT group also had changes in their ACE inhibitor medications during the 6-month intervention; therefore, they were excluded from the resting blood pressure analysis (END = 8; HIT = 8). These patients were included in all other analyses, as their inclusion did not affect the outcomes.

3. Results

There were no differences in baseline patient characteristics, CAD criteria, or medications between MICT and HIIT (Table 1). Exercise compliance was similar between groups. Out of a total of 48 exercise sessions, patients in the MICT and HIIT groups attended 44 ± 4 and 43 ± 5 sessions, respectively ($p = 0.784$). Mean exercise heart rates were higher in the HIIT group compared to MICT (128 ± 16 bpm versus 100 ± 13 bpm, $p = 0.005$), which equated to 82 ± 13% and 66 ± 7% of their age-predicted heart rate maximum ($p = 0.008$). Average external work per session was lower in the HIIT group compared to the MICT group (106 ± 32 kJ versus 197 ± 66 kJ, $p = 0.013$), while total external work over the 6-month training period was not statistically different between groups (8550 ± 3514 kJ vs. 5387 ± 2391 kJ, $p = 0.073$ for MICT vs. HIIT).

Cardiorespiratory fitness outcomes are presented in Table 2, while individual VO_2peak values are presented in Fig. 1. For VO_2peak, there was a time effect for both MICT ($p = 0.003$) and HIIT ($p < 0.001$), such that VO_2peak values were increased at both 3 and 6-months training relative to pretraining. However, there was no difference in the magnitude of increase between groups. Relative to pretraining values, VO_2peak was increased at 3-months training by 19 ± 16% for MICT and 25 ± 14% for HIIT ($p = 0.253$), and 26 ± 29% and 28 ± 17%, respectively, at 6-months training ($p = 0.824$). There was no difference in VO_2peak values between 3 and 6-months training for either group.

All blood pressure and heart rate indices were unchanged with training, with no differences between groups (Table 2; $p \geq 0.05$). All lipid indices were unchanged with training in the HIIT group (Table 2; $p \geq 0.05$). High-density lipoprotein was increased at 6-months training compared to pretraining in the MICT group ($p = 0.030$), while all remaining indices were unchanged with training ($p \geq 0.05$). None of the HRQL subscales or summary scale scores significantly changed with training (Table 2). Self-evaluated health was significantly increased at 6-months compared to both pretraining and 3-months in the MICT group (time effect $p = 0.005$) but was unchanged with training in the HIIT group. Pretraining self-evaluated health was higher in the HIIT group compared to the MICT group ($p = 0.020$).

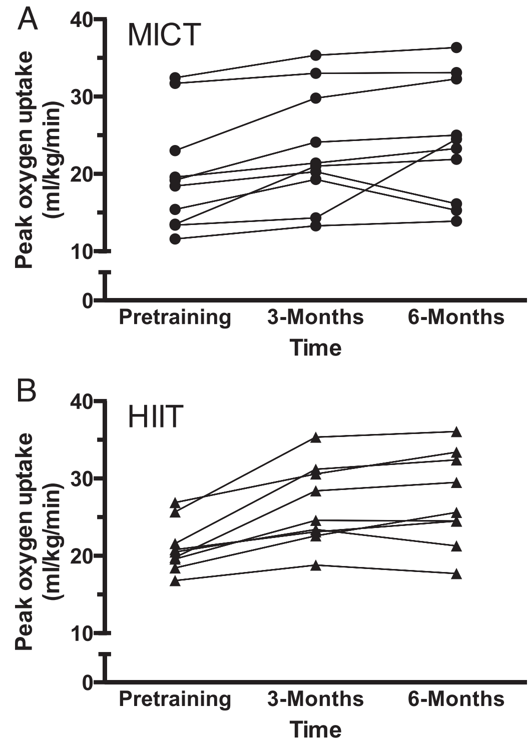

Fig. 1. Individual changes across training period for END (A, closed circles) and HIIT (B, closed triangles). First 3-months entailed exclusive END or HIIT, while remaining 3-months involved END or HIIT plus a standardized resistance training program.

4. Discussion

This study provides the first examination of combined low-volume HIIT and resistance exercise training in a cardiac rehabilitation setting. We found that 3-months of MICT and low-volume HIIT resulted in similar improvements in cardiorespiratory fitness despite HIIT involving less time and less work than MICT. However, contrary to our hypothesis, the additional 3 months of training incorporating resistance exercise did not result in further gains in VO_2peak. Following 6-months of training, the MICT group did experience marginal improvements in self-evaluated health and high-density lipoprotein, while there were no changes in these indices in the low-volume HIIT group. Overall, findings from our study help to delineate the time course of the training-induced changes in patients with CAD. Our results suggest that improvements in fitness with both MICT and low-volume HIIT training occur in the initial 3-months of cardiac rehabilitation training, while other outcomes such as lipids and HRQL benefit from the additional 3-months of training and addition of resistance training.

One of the primary objectives of exercise training in cardiac rehabilitation is to improve cardiorespiratory fitness, given that lower fitness levels are associated with an increased risk of mortality in cardiac patients.[13] Evidence from the meta-analysis of resistance training in cardiac rehabilitation suggests combined MICT and resistance training elicits greater improvements in cardiorespiratory fitness than MICT training alone.[7] To date, only 2 studies have examined the effects of isocaloric HIIT and resistance

Table 2
Changes in cardiovascular risk parameters throughout training.

Variable	END			HIT		
	Pretraining	3-Month	6-Month	Pretraining	3-Month	6-Month
Body composition						
Weight (kg)	79.8 ± 16.6	78.4 ± 17.4	78.2 ± 19.0	90.0 ± 16.2	88.8 ± 15.8	89.3 ± 14.9
BMI (kg m^{-2})	27.3 ± 4.0	27.0 ± 4.3	27.0 ± 4.9	28.9 ± 4.8	28.5 ± 4.9	28.7 ± 4.5
Cardiorespiratory fitness						
VO_2peak (ml kg^{-1} min^{-1})	19.8 ± 7.3	23.2 ± 7.4[a]	24.2 ± 7.8[b]	21.1 ± 3.3	26.4 ± 5.2[a]	27.2 ± 6.0[a]
Peak power output (W)	115 ± 45	145 ± 63[c]	146 ± 72[b]	149 ± 46	188 ± 58[c]	198 ± 63 [a]
Peak HR (bpm)[*]	121 ± 26	120 ± 20	128 ± 29	135 ± 19	142 ± 18	146 ± 16[b]
Resting supine hemodynamics						
Systolic BP (mm Hg)[†]	123 ± 10	117 ± 9	125 ± 14	123 ± 8	120 ± 12	123 ± 9
Diastolic BP(mm Hg)[†]	64 ± 6	60 ± 7	66 ± 6	61 ± 3	63 ± 7	64 ± 5
MAP (mm Hg)[†]	84 ± 7	80 ± 6	86 ± 8	82 ± 3	82 ± 8	84 ± 7
HR (bpm)[*]	58 ± 9	55 ± 7	55 ± 7	60 ± 6	57 ± 7	57 ± 4
Lipid profile						
Cholesterol (mmol/L)	3.53 ± 1.11	3.16 ± 0.80	3.51 ± 0.73	2.79 ± 0.56	2.91 ± 0.49	3.2 ± 1.17
Triglycerides (mmol/L)	0.89 ± 0.22	0.99 ± 0.43	0.88 ± 0.34	0.92 ± 0.22	0.95 ± 0.13	0.92 ± 0.21
HDL (mmol/L)	1.12 ± 0.21	1.06 ± 0.15	1.29 ± 0.32[b]	0.96 ± 0.20	1.07 ± 0.37	1.07 ± 0.17
LDL (mmol/L)	2.03 ± 0.92	1.68 ± 0.64	1.81 ± 0.58	1.42 ± 0.58	1.41 ± 0.55	1.74 ± 1.06
Total cholesterol: HDL	3.16 ± 0.85	3.05 ± 0.97	2.82 ± 0.76	3.06 ± 1.00	2.98 ± 1.16	3.04 ± 1.11
Health related quality of life						
Self-evaluated health transition item	2.7 ± 0.7[e]	3.0 ± 1.1[d]	4.0 ± 0.7[c]	4.2 ± 1.2	4.4 ± 0.9	4.8 ± 0.7
Eight subscales						
Physical functioning	24.4 ± 5.7	22.7 ± 6.6	24.3 ± 6.4	25.7 ± 5.4	23.7 ± 7.4	24.1 ± 7.9
General health	21.1 ± 3.7	19.5 ± 3.4	21.8 ± 2.7	19.4 ± 1.5	19.4 ± 3.0	20.8 ± 3.3
Role-physical	6.1 ± 1.8	6.9 ± 1.6	6.7 ± 1.7	6.7 ± 1.9	6.6 ± 1.7	7.5 ± 0.8
Bodily pain	9.0 ± 2.3	8.7 ± 2.6	9.3 ± 2.2	8.6 ± 2.4	9.5 ± 1.3	8.9 ± 2.0
Mental health	24.9 ± 3.3	24.4 ± 4.1	24.1 ± 3.9	25.9 ± 2.7	27.0 ± 1.9	26.2 ± 2.8
Role-emotional	5.3 ± 1.3	4.5 ± 1.6	5.3 ± 1.3	5.1 ± 1.5	5.3 ± 1.2	5.4 ± 0.9
Vitality	17.1 ± 2.9	14.6 ± 3.2	16.8 ± 3.6	18.5 ± 4.2	17.3 ± 3.0	18.6 ± 6.1
Social functioning	8.8 ± 1.3	9.2 ± 1.2	9.3 ± 0.9	8.3 ± 1.9	9.3 ± 1.0	8.9 ± 1.7
Two summary scores						
Mental health	56.1 ± 4.1	52.4 ± 8.9	56.9 ± 6.3	57.0 ± 6.1	60.5 ± 4.4	61.8 ± 5.3
Physical health	62.1 ± 9.7	60.1 ± 10.4	63.4 ± 9.6	61.5 ± 7.4	63.5 ± 7.7	64.8 ± 9.2

Values are mean ± SD. BMI, body mass index; BP, blood pressure; HDL, high-density lipoprotein; HR, heart rate; LDL, low-density lipoprotein; MAP, mean arterial pressure; VO_2peak, peak oxygen uptake.

[a] $p \leq 0.001$ vs. pretraining within-group.
[b] $p < 0.05$ vs. pretraining within-group.
[c] $p < 0.01$ vs. pretraining within-group.
[d] $p < 0.05$ vs. 6-months within-group.
[e] $p < 0.05$ vs. HIT pretraining.
[*] Analysis on $n = 17$ (END = 9; HIT = 8).
[†] Analysis on $n = 16$ (END = 8; HIT = 8).

training in patients with CAD, with both studies demonstrating improvements in VO_2peak following 2[8] and 4-months[2] of training. Due to their study designs, it is difficult to determine whether the improvements in VO_2peak were attributed to the aerobic or resistance components, or the combination of both. The design of the present study enabled the examination of low-volume HIIT both alone and in combination with resistance training. We observed an improvement in VO_2peak following 3-months of both MICT and HIIT, but no further increases at 6-months with the addition of resistance training. Our observations at 3-months of training were expected, given previous evidence of improvements in VO_2peak following 3-months[1,14,15] of HIIT and MICT training in patients with CAD. It is worth noting our low-volume HIIT required less time (20 min versus 30–50 min) and involved less total external work per exercise session than the MICT group, and still elicited a comparable improvement in cardiorespiratory fitness. This is supported by previous low-volume HIIT investigations in healthy[16,17] and CAD[4] populations, suggesting short bouts of high-intensity exercise are a sufficient exercise stimulus for training adaptations.

It is unknown why the addition of resistance training at 3-months did not elicit further improvements in VO_2peak, as presently there is no study which has used a similar study design. To date, few studies have examined the time course of fitness improvements with supervised exercise training in CAD. Moholdt et al.[18] observed improvements in VO_2peak in as early as 4 weeks of supervised MICT and isocaloric HIIT training. However, when patients were asked to continue exercising unsupervised, the MICT group experienced no further improvements at 6-month follow up, while the HIIT group increased VO_2peak further. Conversely, another study demonstrated that the improvements obtained after 3-months of supervised MICT and isocaloric HIIT were abolished when patients were followed up at 6 and 30-months following the cessation of supervised exercise training.[15] In sedentary women, Astorino et al.[19] observed a plateau in VO_2peak following 9 weeks of HIIT training. At 6-months training, we observed a 26% and 28% increase in VO_2peak in the MICT and HIIT groups, respectively, which is superior to previous observations of improvements after 6-months of HIIT (17%),[20] MICT (11%),[21] and combined MICT and resistance training (9.8–18%)[21,22] in patients with CAD. Our findings are also greater than a study employing no exercise for 6-months following a CAD event, which observed an 8% increase in VO_2peak,[20] and suggest our improvements were attributed to the MICT and HIIT interventions. The absence of an increase in VO_2peak from 3 to 6-months is likely not attributed to an insufficient exercise stimulus, but likely indicates that patients reached the maximum obtainable level of cardiorespiratory fitness during the first 3-months of aerobic training, and the addition of resistance training could not stimulate further increases.

Following a cardiac event, individuals typically have lower HRQL in comparison to the general population,[23,24] which is

independently associated with increased mortality and readmission to the hospital.[25] This intervention proved to be marginally successful at targeting HRQL since increases in self-evaluated health were only observed following 6-months of MICT training. Changes in self-evaluated health were only observed following the addition of resistance training after the first 3 months suggesting that resistance training may be a crucial component in effecting changes in HRQL. A second plausible explanation may be that it requires greater than 3-months of training to elicit these changes in self-perceived health in this population. There is also evidence of improvements in HRQL without exercise training as the time post-CAD event progresses.[26] Given that this study did not include a control exercise group, it is possible the observed increase in HRQL at 6-months training was also attributed to this natural recovery in health perceptions. In this study low-volume HIIT alone or in combination with resistance training, had no effects on HRQL, which may be attributed to the significantly higher pretraining scores in the HIIT versus MICT group. Apart from the single-item self-evaluated health question we did not observe any other changes in HRQL following the intervention, which is in contrast to previous cardiac rehabilitation studies.[1,14,27] A likely explanation for the lack of change in the present study is that participants mean initial scores on the subscales were all at least 75% of the maximal attainable score and at least 80% for the summary scores, thereby making further increases difficult to obtain. These high pretraining values could be attributed to the time post-CAD event (5–6 months), and the natural recovery of HRQL.

Supine brachial artery blood pressures and heart rates were unchanged across the 6-month training period in both exercise groups, which is line with previous examinations of HIIT and MICT training[1,2,14] and combined resistance training with MICT and HIIT programs[2] in CAD patients. Blood lipid profiles were also unchanged with training in both groups, except for high-density lipoprotein which was increased in the MICT group following 6-months of training. The observation of unchanged lipid profiles with aerobic training in this population is in contrast to previous literature.[1,15,28] However all patients were receiving medical management for an average of 5 months prior to initiating exercise training. Pretraining hemodynamics and lipid profiles were in a normal range, which is likely attributed to the period of optimal medical management and explains the absence of a training effect.

In total, 29% of our sample dropped out of the outpatient cardiac rehabilitation program, with 3 dropping out in the first few weeks and 5 dropping out in the final 3 months. While program attrition reduced our sample size and influences our statistical analyses, the attrition rate observed in this study is representative of average dropout rates in cardiac rehabilitation.[29] Diet and outside exercise was not controlled for; therefore changes in either behavior during the 6-month training period may have affected our outcomes. Finally, phase II cardiac rehabilitation programs are generated initiated within weeks of a CAD event. In the present study, exercise training was initiated on average 5–6 months following their event. It is possible the prolonged time post-CAD event may have influenced their pretraining state, and that greater gains may have been observed if training were initiated earlier.

5. Conclusions

Substantial improvements in cardiorespiratory fitness were observed following 3-months of low-volume HIIT and MICT in patients with CAD. The addition of resistance training for 3 months elicited no further improvements in VO_2peak, but may have contributed to the improvements in lipids and HRQL in the MICT group. While the results from this pilot study may suggest MICT combined with resistance training was more efficacious, between-group differences in pretraining values may have been a confounding factor. Given the important of resistance training in cardiac rehabilitation, additional studies are required to determine the effects of resistance training combined with both isovolumetric and low-volume HIIT. In order to accurately decipher these relationships, future examinations should consider introducing resistance training at an earlier time point. In any case, our observation of the improvement and maintenance of fitness with low-volume HIIT supports the continued investigation of this innovative and time effective exercise prescription for patients in cardiac rehabilitation settings.

Practical implications

- Improvements in fitness are obtainable with a shorter duration of exercise (i.e. 20 min), as long as the exercise session incorporates bouts of high-intensity exercise.
- Improvements in fitness with aerobic exercise training appear to plateau by 3-months in patients with coronary artery disease.
- Endurance exercise combined with resistance training is capable of improving health related quality of life and lipid profiles in patients with coronary artery disease.

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References

1. Wisloff U, Stoylen A, Loennechen JP et al. Superior cardiovascular effect of aerobic interval training versus moderate continuous training in heart failure patients: a randomized study. *Circulation* 2007; 115(24):3086–3094.
2. Warburton DE, McKenzie DC, Haykowsky MJ et al. Effectiveness of high-intensity interval training for the rehabilitation of patients with coronary artery disease. *Am J Cardiol* 2005; 95(9):1080–1084.
3. Rognmo Ø, Hetland E, Helgerud J et al. High intensity aerobic interval exercise is superior to moderate intensity exercise for increasing aerobic capacity in patients with coronary artery disease. *Eur J Cardiovasc Prev Rehabil* 2004; 11(3):216–222.
4. Currie KD, Dubberley JB, McKelvie RS et al. Low-volume, high-intensity interval training in patients with CAD. *Med Sci Sports Exerc* 2013; 45(8):1436–1442.
5. Balady GJ, Williams MA, Ades PA et al. Core components of cardiac rehabilitation/secondary prevention programs: 2007 update: a scientific statement from the American Heart Association Exercise, Cardiac Rehabilitation, and Prevention Committee, the Council on Clinical Cardiology; the Councils on Cardiovascular Nursing, Epidemiology and Prevention, and Nutrition, Physical Activity, and Metabolism; and the American Association of Cardiovascular and Pulmonary Rehabilitation. *Circulation* 2007; 115(20):2675–2682.
6. Stone JA, McCartney N, Millar PJ et al. Risk stratification, exercise prescription, and program safety, in *Guidelines for cardiac rehabilitation and cardiovascular disease prevention: translating knowledge into action*, 3rd ed., Stone JA, editor, Winnipeg, Canadian Association of Cardiac Rehabilitation, 2009, [chapter 10].
7. Marzolini S, Oh PI, Brooks D. Effect of combined aerobic and resistance training versus aerobic training alone in individuals with coronary artery disease: a meta-analysis. *Eur J Prev Cardiol* 2012; 19(1):81–94.
8. Gremeaux M, Hannequin A, Laurent Y et al. Usefulness of the 6-minute walk test and the 200-metre fast walk test to individualize high intensity interval and continuous exercise training in coronary artery disease patients after acute coronary syndrome: a pilot controlled clinical study. *Clin Rehabil* 2011; 25(9):844–855.
9. Currie KD, McKelvie RS, MacDonald MJ. Brachial artery endothelial responses during early recovery from an exercise bout in patients with coronary artery disease. *Biomed Res Int* 2014:1–8.
10. Astorino TA, Robergs RA, Ghiasvand F et al. Incidence of the oxygen plateau at VO_2max during exercise testing to volitional fatigue. *J Exerc Physiol Online* 2000; 3(4):1–12.
11. Ware Jr JE, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Med Care* 1992; 30(6):473–483.
12. Little JP, Gillen JB, Percival ME et al. Low-volume high-intensity interval training reduces hyperglycemia and increases muscle mitochondrial capacity in patients with type 2 diabetes. *J Appl Physiol* 2011; 111(6):1554–1560.

13. Kavanagh T, Mertens DJ, Hamm LF et al. Prediction of long-term prognosis in 12 169 men referred for cardiac rehabilitation. *Circulation* 2002; 106(6):666–671.
14. Moholdt T, Aamot IL, Granoien I et al. Aerobic interval training increases peak oxygen uptake more than usual care exercise training in myocardial infarction patients: a randomized controlled study. *Clin Rehabil* 2012; 26(1):33–44.
15. Moholdt T, Aamot IL, Granoien I et al. Long-term follow-up after cardiac rehabilitation: a randomized study of usual care exercise training versus aerobic interval training after myocardial infarction. *Int J Cardiol* 2011; 152(3):388–390.
16. Astorino TA, Allen RP, Roberson DW et al. Effect of high-intensity interval training on cardiovascular function, VO_2 max, and muscular force. *J Strength Cond Res* 2012; 26(1):138–145.
17. Rakobowchuk M, Tanguay S, Burgomaster KA et al. Sprint interval and traditional endurance training induce similar improvements in peripheral arterial stiffness and flow-mediated dilation in healthy humans. *Am J Physiol Regul Integr Comp Physiol* 2008; 295(1):R236–R242.
18. Moholdt TT, Amundsen BH, Rustad LA et al. Aerobic interval training versus continuous moderate exercise after coronary artery bypass surgery: a randomized study of cardiovascular effects and quality of life. *Am Heart J* 2009; 158(6):1031–1037.
19. Astorino TA, Schubert MM, Palumbo E et al. Magnitude and time course of changes in maximal oxygen uptake in response to distinct regimens of chronic interval training in sedentary women. *Eur J Appl Physiol* 2013; 113(9):2361–2369.
20. Munk PS, Staal EM, Butt N et al. High-intensity interval training may reduce in-stent restenosis following percutaneous coronary intervention with stent implantation A randomized controlled trial evaluating the relationship to endothelial function and inflammation. *Am Heart J* 2009; 158(5): 734–741.
21. Marzolini S, Oh PI, Thomas SG et al. Aerobic and resistance training in coronary disease: single versus multiple sets. *Med Sci Sports Exerc* 2008; 40(9): 1557–1564.
22. Pierson LM, Herbert WG, Norton HJ et al. Effects of combined aerobic and resistance training versus aerobic training alone in cardiac rehabilitation. *J Cardiopulm Rehabil* 2001; 21(2):101–110.
23. Jette DU, Downing J. Health status of individuals entering a cardiac rehabilitation program as measured by the medical outcomes study 36-item short-form survey (SF-36). *Phys Ther* 1994; 74(6):521–527.
24. Stewart AL, Greenfield S, Hays RD et al. Functional status and well-being of patients with chronic conditions. Results from the Medical Outcomes Study. *JAMA* 1989; 262(7):907–913.
25. Spertus JA, Jones P, McDonell M et al. Health status predicts long-term outcome in outpatients with coronary disease. *Circulation* 2002; 106(1):43–49.
26. Oldridge N, Guyatt G, Jones N et al. Effects on quality of life with comprehensive rehabilitation after acute myocardial infarction. *Am J Cardiol* 1991; 67(13):1084–1089.
27. Beniamini Y, Rubenstein JJ, Zaichkowsky LD et al. Effects of high-intensity strength training on quality-of-life parameters in cardiac rehabilitation patients. *Am J Cardiol* 1997; 80(7):841–846.
28. Hansen D, Eijnde BO, Roelants M et al. Clinical benefits of the addition of lower extremity low-intensity resistance muscle training to early aerobic endurance training intervention in patients with coronary artery disease: a randomized controlled trial. *J Rehabil Med* 2011; 43(9):800–807.
29. Worcester MU, Murphy BM, Mee VK et al. Cardiac rehabilitation programmes: predictors of non-attendance and drop-out. *Eur J Cardiovasc Prev Rehabil* 2004; 11(4):328–335.