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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 ± 7.4 ml kg^{-1} min^{-1}; high-intensity interval: 21.1 ± 3.3 vs. 26.4 ± 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 $\geq$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 $\geq$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