ORIGINAL RESEARCH

High-Intensity Interval Versus Moderate-Intensity Continuous Training in Cardiac Rehabilitation

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ABSTRACT

Background: Past research has compared the effects of moderate-intensity continuous training (MCT) versus high-intensity interval training (HIIT) in phase 2 cardiac rehabilitation patients, but with conflicting results. Therefore, the purpose of this study was to evaluate if HIIT leads to greater improvements in functional capacity when compared with MCT in a group of phase 2 cardiac rehabilitation patients.
Methods: Eighteen patients in a phase 2 cardiac rehabilitation program completed precardiopulmonary and postcardiopulmonary exercise tests, a 12-min walk test (12MWT), and resting blood pressure (BP). After 2 weeks of run-in, patients were randomly assigned to 10 weeks of HIIT (alternating periods of 80%–90% heart rate [HR] reserve and 60%–70% HR reserve) or MCT (60%–80% HR reserve) exercise group. Changes in VO_2 peak, 12MWT distance, and BP (mm Hg) were analyzed by independent *t* test.
Results: The average patient was 65 years old, 1.75 m tall, and overweight. VO_2 peak values improved for individuals in both exercise modalities. There was no significant difference between the exercise groups ($P = 0.174$). In addition, both groups improved their 12MWT distance, resting systolic, and diastolic BP (DBP), with no significant difference in improvements between the 2 exercise groups.
Conclusion: In this study, HIIT was not more effective than MCT for improving functional capacity in a group of phase 2 cardiac rehabilitation patients. However, since HIIT was equally effective compared with MCT in several measures, it provides another option for exercise prescription to the traditional prescription for this population. *Journal of Clinical Exercise Physiology*. 2020;9(1):10–16.

Keywords: high-intensity interval training (HIIT), VO_2 peak, 12-minute walk test (12MWT)

INTRODUCTION

For people who have experienced a cardiac event, cardiac rehabilitation is effective in improving recovery rates and reducing future cardiac complications (1–3). However, there is still debate regarding what the optimal intensity and type of exercise training is for patients who have experienced a cardiac event (4). Moderate-intensity continuous training (MCT) is routinely prescribed for cardiac patients in phase 2 cardiac rehabilitation. MCT exercise is typically rated as "fairly light" to "somewhat hard" in terms of target intensity level. This intensity of exercise is performed continuously for 10 to 30 min.

High-intensity interval training (HIIT) has been used as an effective type of training in healthy adults for many years

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(5); however, routine implementation of HIIT into phase 2 cardiac rehabilitation programs for higher risk cardiac patients has yet to be established. The HIIT process allows patients to work at a higher intensity for a duration while alternating with recovery intervals at a lower intensity, or sometimes alternated with rest.

Many studies have compared the effect of interval training on overall exercise capacity (6–24). Some studies that have directly compared the effects of HIIT and MCT have reported that HIIT produced greater improvements in exercise capacity compared with MCT (6–8). In contrast, other studies have found no significant difference between the improvements of oxygen consumption (VO_2) peak (10,14,23). A potential explanation for differences in these results could be related to differences in the duration of the training program, interval time, and work-to-rest ratios. Each of these factors is an important factor in the effectiveness of both HIIT and MCT.

There is also some evidence that HIIT can improve resting blood pressure (BP) in older adults. For example, Grace et al. (24) reported significant reductions in systolic BP (SBP), mean arterial pressure, and rate pressure product in sedentary older men following 6 weeks of HIIT. In those with metabolic syndrome, a single bout of HIIT lowered BP better than MCT in subjects that were hypertensive (25). However, a recent meta-analysis concluded that MCT and HIIT have equal effects reducing BP in those with hypertension (26).

The potential benefits of HIIT in cardiac rehabilitation are evident. However, there still exists a lack of uniformity in reported findings. Therefore, the aims of this study were to determine if an HIIT protocol would lead to greater improvements in functional capacity, as measured by VO_2 peak and 12-min walk test (12MWT) distance, and resting BP compared with MCT in patients enrolled in a phase 2 cardiac rehabilitation program.

METHODS

All procedures were approved by the Bowling Green State University Institutional Review Board and the University of Toledo Institutional Review Board before any study activities took place.

Participants

Patients admitted to a phase 2 cardiac rehabilitation program in the Midwestern United States were approached to volunteer for this study during the period of September 2016 to February 2017. Inclusion criterion included the following: at least 45 years old, left ventricular ejection fraction ≥40%, more than 3 weeks postmyocardial infarction or percutaneous intervention, and at least 4 weeks postcoronary artery bypass graft surgery. Patients must have attended 4 of the first 6 rehabilitation sessions, which was classified as the run-in period, and have been free of any comorbidity, such as neuropathy or lower leg injury, that would limit them from undergoing treadmill exercise.

Procedures

Participants were recruited from patients admitted into the phase 2 cardiac rehabilitation program at the University of Toledo Medical Center. Each patient participated in the study for 12 weeks, 3 times per week. Patients were also encouraged to be more active on their own, but this was not measured. The first 2 weeks were the run-in period, which consisted of standard phase 2 cardiac rehabilitation therapy, 12MWT, and a cardiopulmonary exercise test (CPX). Eligible patients were then randomized into either HIIT or MCT exercise groups. Participants then completed 10 weeks of the assigned MCT or HIIT exercise training under supervision of a clinical exercise physiologist who monitored heart rate (HR) by electrocardiogram telemetry to ensure proper intensity adherence. If HR was not in the correct range, the workload was modified by the clinical exercise physiologist.

Patients in the MCT group completed a 5-min active warm up (slow walking on a track) and 35 min of cardiorespiratory training at 60% to 80% of their HR reserve (HRR). This intensity was selected because it matched what is usually prescribed during cardiac rehabilitation at this facility. Exercise was primarily performed on a treadmill (~80% of the time), followed by 5 min of active cool down (slow walking on a track).

Patients in the HIIT group completed a 5-min active warm up, 36 min of cardiorespiratory training primarily on treadmills (but patients were free to choose from several different modalities), and 5 min of active cool down on a track. The cardiorespiratory training for the HIIT exercise group included 6 intervals, which consisted of a 3-min period of higher intensity work intervals at an intensity of 80% to 90% HRR followed by a 3-min active recovery period at an intensity of 60% to 70% HRR.

The MCT and HIIT exercise groups completed a total of 45 and 46 min of cardiovascular training during each exercise session, including warm up and cool down, respectively. All patients ended each rehabilitation session by participating in 15 min of resistance training using weights and stretching, for a combined total of 60 and 61 min per cardiac rehabilitation session for the MCT and HIIT exercise groups, respectively. All participants attended group education sessions and received individual counseling from a registered dietitian, a clinical exercise physiologist, and a registered nurse. A follow-up 12MWT and CPX test were completed during the last 2 weeks of the study. To be considered "completed," patients must have attended at least 90% of sessions and finished all posttesting.

Measures

Demographic data were collected on all patients, including age (years), height (m), weight (kg), and body mass index (BMI). In addition, ejection fraction (%) and cardiovascular diagnoses were collected from medical records. Resting HR (RHR), SBP, and DBP were measured in the seated position at the beginning of each session prior to any testing or cardiorespiratory training.

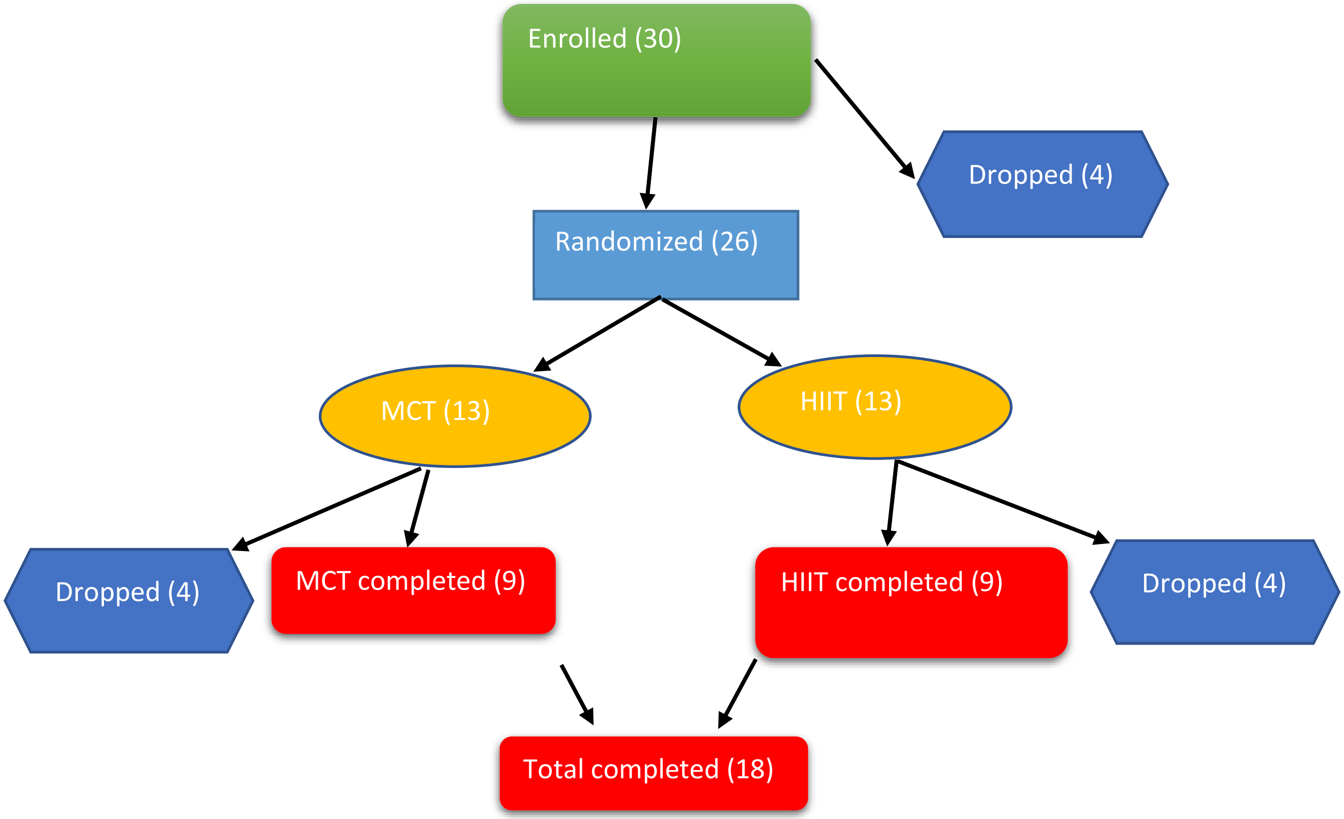

FIGURE 1. Consort diagram. MCT = moderate-intensity continuous training; HIIT = high-intensity interval training; Dropped = patient discontinued cardiac rehabilitation participation.

Exercise capacity was evaluated using a CPX test via the Modified-Balke Treadmill Protocol as described elsewhere (21). Measurement of gas exchange was used to evaluate the patient's exercise capacity via a metabolic cart (MGC Diagnostics, Minneapolis, Minnesota). BP was measured during rest and every 2 min during the exercise test and at the end of the 10-min recovery period. HR was measured continuously via the electrocardiogram from rest until the end of the 10-min postexercise observation.

Functional capacity was evaluated through the use of the 12MWT as described previously (27). Though the 6-min walk test (6MWT) is more commonly used, the 12MWT has the advantage of being a better method to evaluate fitness in patients with higher exercise capacity (28). The 12MWT has similar reproducibility as the 6MWT (29) and is reliable and valid (30).

Statistics

Data were analyzed using IBM's SPSS (v21, IBM, Armonk, New York). Patient baseline characteristics were compared using an independent *t* test. Differences between groups following training were also analyzed using an independent *t* test, 2 tailed. For all the analyses a $P < 0.05$ was accepted as significant.

RESULTS

After screening, the total number of patients enrolled was 30 (see Figure 1). Following randomization, there was no difference in the distribution of cardiac diagnoses (see Table 1). Of the 30 patients enrolled, 18 completed the entire study and were included in the analysis. Four patients were dropped between enrollment and randomization due to noncompliance with appointments. After randomization, each group had 4 patients drop. In the MCT group, reasons for dropping were as follows: moved out of town (n = 1), noncompliance with appointments (n = 1), and noncardiac-related health complications (n = 2). In the HIIT group, reasons for dropping were as follows: returning to work (n = 1), withdrew consent (n = 1), and noncardiac-related health complications (n = 2). This represents a slightly lower dropout rate than is typical for cardiac rehabilitation.

TABLE 1. Number of diagnoses in each exercise training group.[a]

Diagnosis	MCT (n = 9)	HIIT (n = 9)
Myocardial infarction	2	1
Stent/PTCA	3	5
Stable angina	1	1
Coronary artery bypass graft	2	2
Valve surgery	1	0

[a]MCT = moderate-intensity continuous training; HIIT = high-intensity interval training; PTCA = percutaneous transluminal coronary angioplasty

TABLE 2. Comparison of HIIT and MCT baseline patient characteristics.[a]

Characteristic	MCT Group (n = 9)	HIIT Group (n = 9)	*P* Value
Age (years)	63.67 ± 9.02	66.00 ± 5.12	0.510
Height (m)	1.70 ± 0.073	1.83 ± 0.050	0.001*
Weight (kg)	82.22 ± 19.14	91.31 ± 27.23	0.425
BMI	27.59 ± 5.01	27.31 ± 6.35	0.918
Ejection fraction (%)	51.67 ± 9.68	55.22 ± 11.25	0.483

[a]Values are mean ± standard deviation. MCT = moderate-intensity continuous training; HIIT = high-intensity interval training; BMI = body mass index
*Significance at $P < 0.05$

Baseline and Outcome Measures

Patient characteristics were used to evaluate if the 2 exercise groups were similar and are included in Table 2. The only significant difference in patient characteristics between the 2 exercise groups was height ($P = 0.001$). However, of those completing the study, only 2 were female, both of whom were in the HIIT group. In addition, all baseline outcome variables, including peak VO_2, 12MWT distance, RHR, and BP, were not significantly different between the 2 exercise groups (Table 3). There were no adverse events during exercise testing or training.

Results of the CPX test indicate that the MCT and HIIT exercise groups improved their exercise capacity by an average of 2.25 and 2.94 $mL \cdot kg^{-1} \cdot min^{-1}$, respectively. There was no difference in the improvement of peak VO_2 between the groups ($P = 0.173$). In addition, results of the post-12MWT indicate that the MCT and HIIT exercise groups improved their 12MWT distance by 88 and 171 m, respectively. There was no significant difference in the distance walked during the 12MWT between the 2 exercise groups after exercise training ($P = 0.096$).

Changes in RHR and BP

Following training, the MCT exercise group did not change RHR, with a slight increase in RHR of 1 $b \cdot min^{-1}$. The HIIT exercise group had a decrease in RHR of 6 $b \cdot min^{-1}$. There was a difference in the change in RHR between the exercise groups ($P = 0.033$).

Participants in both groups had a reduction in resting SBP following training, but there was no significant difference between the groups (Table 4). Interestingly, the MCT group had an increase in DBP of 1.6 mm Hg, but the HIIT exercise group decreased their DBP by 3.1 mm Hg (Table 4). These changes were not statistically different.

DISCUSSION

Participants in both the MCT and HIIT groups improved their VO_2 peak and 12MWT during this study, but contrary to the hypothesis, the HIIT group did not improve more than the MCT group in these measures. Although HIIT was not more effective than MCT, these data do suggest that HIIT can be an effective intervention for improving functional and exercise capacity and can be chosen as an alternative to MCT. However, a supposed advantage of HIIT is a decreased time commitment to exercise, i.e., the same benefits in a shorter period of time (31). That was not the case in this study.

Changes in Peak VO_2

Peak VO_2 is known to be a strong predictor of overall mortality (22). Thus, it is important to improve peak VO_2 in those who have cardiovascular disease. Peak VO_2 can be improved through MCT and HIIT, but optimal training intensity and duration to improve peak VO_2 using HIIT has yet to be determined. Multiple studies suggest that the use of HIIT with phase 2 cardiac rehabilitation patients may lead to greater improvements in peak VO_2 when compared with MCT (6–8). Findings from our study suggest that both MCT

TABLE 3. Comparison of HIIT and MCT testing variables at baseline.[a]

Variable	MCT Group	HIIT Group	*P* Value
Peak VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$)	18.52 ± 4.95	21.22 ± 6.40	0.32
12MWT distance (m)	870 ± 173	916 ± 179	0.57
12MWT RHR ($b \cdot min^{-1}$)	75 ± 11	72 ± 12	0.57
12MWT resting SBP (mm Hg)	130 ± 21	128 ± 17	0.82
12MWT resting DBP (mm Hg)	72 ± 12	75 ± 11	0.60

[a]Values are mean ± standard deviation. MCT = moderate-intensity continuous training; HIIT = high-intensity interval training; VO_2 = volume of oxygen consumed; 12MWT = 12-minute walk test; RHR = resting heart rate; SBP = systolic blood pressure; DBP = diastolic blood pressure

TABLE 4. Changes in outcome variables.[a]

Variable	MCT			HIIT			
	Pre	Post	Change	Pre	Post	Change	*P* Value
Peak VO_2 (mL·kg^{-1}·min^{-1})	18.52 ± 4.95	20.75 ± 3.93	+2.23	21.22 ± 6.40	24.14 ± 5.95	+2.92	0.17
12MWT distance (m)	870 ± 173	958 ± 100	+88.05	916 ± 179	1087 ± 194	+171.33	0.10
RHR (b·min^{-1})	75 ± 11	76 ± 11	+1.11	72 ± 12	66 ± 8.43	–5.9	0.03*
Resting SBP (mm Hg)	130 ± 21	126 ± 19	–4.00	128 ± 17	123 ± 17.30	–5.11	0.72
Resting DBP (mm Hg)	72 ± 12	74 ± 10	+1.56	75 ± 11	72 ± 13	–3.09	0.72

[a]Values are mean ± standard deviation. MCT = moderate-intensity continuous training; HIIT = high-intensity interval training; VO_2 = volume of oxygen consumed; 12MWT = 12-minute walk test; RHR = resting heart rate; RSBP = resting systolic blood pressure; RDBP = resting diastolic blood pressure
*Significance at $P < 0.05$

and HIIT exercise training protocols increase peak VO_2. Although there was no statistically significant difference in peak VO_2 between the 2 groups, there were greater absolute improvements following HIIT compared with MCT. While both groups improved, in the HIIT group, the absolute improvement in peak VO_2 (2.92 mL · kg^{-1} · min^{-1}) is nearly 1 metabolic equivalent (MET). In previous work, an increase of 1 MET was associated with a 13% decrease in risk of all mortality and coronary heart disease (32).

Improvements in peak VO_2 in the HIIT groups from the works of Freyssin et al. (4) and Keteyian et al. (12) are very similar to those of the present study. In all 3 studies, the HIIT exercise groups improved their peak VO_2 by approximately 3 mL · kg^{-1} · min^{-1}. However, improvements in peak VO_2 in the MCT group were not similar across all 3 studies. In the Freyssin et al. and Keteyian et al. studies, the MCT group only improved their peak VO_2 by 0.2 and 0.7 mL · kg^{-1} · min^{-1}, respectively (4,12). Both of these were lower than the present study. Differences in results from previous studies as compared with the current study may be attributed to differences in the intensity and duration while performing MCT.

Changes in 12MWT Distance

Distance walked during a 12MWT is an objective measure of functional capacity and is a more appropriate test than the 6MWT in cardiac rehabilitation patients with higher fitness (28). Previous studies have determined that the 12MWT is a valid and reliable test to measure functional capacity in those with coronary heart disease (27). Our study is the first to compare the change in 12MWT distance following MCT or HIIT. However, similar to our findings, Freyssin et al. used the 6MWT to compare the effects of MCT versus HIIT and reported that both groups improved their distance walked similarly (4).

Changes in RHR and BP Responses

Typically, with aerobic exercise training there is a decrease in RHR, with an associated reduction in the risk for cardiovascular disease (33). However, the MCT group's RHR increased by a minor nonsignificant amount, the opposite of what was expected. Even though these results suggest that MCT does not improve RHR, previous studies have found that 8 weeks of MCT reduced RHR by 2 to 4 b · min^{-1} (12,34). There are many factors that affect RHR, such as medications and psychological factors, including experiencing anxiety or stress. These factors could have contributed to the unexpected lack of change in RHR in the MCT group.

Resting BP is also often lower following aerobic training primarily due to decreased activity of the sympathetic nervous system and the improvement in peripheral vascular resistance (35). Both resting SBP and DBP were evaluated in the study, but with no significant difference in the changes between the groups. BP has been reported to improve similarly between groups performing MCT and HIIT exercise (36). Similarly to HR, BP response is sensitive to medications (e.g., beta blockers), environmental factors (e.g., temperature), physiology (e.g., state of hydration), and psychological issues (e.g., anxiety and stress). It is unclear in this case why we did not observe overall reductions in BP.

Limitations and Future Research

In this study, exercise duration was equal between the MCT and HIIT exercise groups. However, energy expenditure most likely was different. The HIIT group exercised at a higher intensity during their work interval (80%–90% of HRR) compared with the MCT group (60%–80% of HRR). During the HIIT group's recovery interval, they were working within the intensity range that the MCT group was given to exercise within for the duration of the study. Due to the HIIT group being required to work at a higher intensity, they most likely expended more energy compared with the MCT group. Future research should evaluate whether there is a difference in functional capacity improvement when energy expenditure between the groups is equal.

Physical activity performed outside of rehabilitation was not assessed. This may have led to a wide variety in the amount of physical activity completed between the 2 exercise groups and as a result could have affected the outcomes variables response.

There were patients who did not complete the program for a variety of reasons, including returning to work, nonadherence, noncardiac-related health complications, and deciding to no longer participate. It is very common for phase 2 cardiac rehabilitation patients to be nonadherent to the exercise program, but the dropout rate in our study was lower than typically occurs in cardiac rehabilitation programs. However, the dropout that did occur reduced the sample size to a smaller level than previous studies and may have led to our study being underpowered to detect differences in the outcome measures.

Patients in the HIIT group were significantly taller than those in the MCT group. It is unknown why this occurred. However, this could have had an impact in walking speed and therefore the 12MWT. There were also predominately males in the study, and future studies should attempt a better balance of males and females.

Finally, we attempted to recruit a representative sample from cardiac rehabilitation, which meant that, within our inclusion criteria, there were some much older than others. Some older adults can respond differently to the stimulus of exercise training. However, there was no difference in age between the groups in our study. We also did not gather data about body composition (only BMI) or caloric intake on these subjects, which would be helpful to do in future research.

CONCLUSIONS

Our results indicate that HIIT was not superior to MCT in terms of VO_2 max improvement or 12MWT, as was hypothesized. However, we can expect to see improvement in functional capacity in patients performing either MCT or HIIT exercise in phase 2 cardiac rehabilitation. In addition, the HIIT group did not experience any cardiac arrhythmias, excessive HR responses, or other untoward events during the rehabilitation sessions. This adds to the existing literature suggesting that supervised HIIT exercise is safe for patients with a variety of cardiac diagnoses when undergoing treatment in a phase 2 cardiac rehabilitation program.

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