

Benefits and Risks of High-Intensity Interval Training in Patients With Coronary Artery Disease



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Exercise-based cardiac rehabilitation is integral to secondary prevention in patients with coronary artery disease. Recently, the effectiveness and “superiority” of high-intensity interval training (HIIT) is a purported time-saving alternative to “traditional” moderate-intensity continuous training (MICT) in cardiac rehabilitation. The rationale for HIIT adoption is, however, not fully substantiated in the scientific literature. Established guidelines for exercise testing and training, when carefully adhered to, reduce the likelihood of triggering a cardiac event or inducing musculoskeletal injury. Clinicians should likewise consider patient risk stratification and introduce HIIT as an alternative to MICT only after patients exhibit stable and asymptomatic responses to vigorous exercise training. Although HIIT adherence appears comparable with MICT during outpatient rehabilitation, compliance drops dramatically for unsupervised exercise. Despite the enthusiasm surrounding HIIT, its main advantage over MICT appears to be short-term exercise performance outcomes and indices of vascular function. Regarding benefits to cardiovascular disease risk factor modification, management of vital signs, and measures of cardiac performance, current evidence indicates that HIIT does not outperform MICT. Long-term outcomes to HIIT are currently uncertain and logistical constraints to HIIT incorporation need additional clarification. Based on these limited findings, derived from facilities and clinicians at the forefront of cardiac rehabilitation, the routine adoption of HIIT should be viewed cautiously. In conclusion, the current review highlights numerous specific research directives that are needed before the safety and effectiveness of HIIT can be confirmed and widely adopted in patients with known or suspected coronary artery disease, especially in unsupervised, nonmedical settings. © 2019 Elsevier Inc. All rights reserved. (Am J Cardiol 2019;123:1370–1377)

Atherosclerotic cardiovascular disease remains a major public health concern. Nonetheless, recent clinical and scientific evidence supports the fact regular cardiovascular exercise participation is in the most potent lifestyle therapies to treat coronary artery disease (CAD).¹ The overall influence of exercise rehabilitation on CAD morbidity, however, remains limited by referral rates, poor program adherence, and competing time obligations.² Additionally, baseline exercise capacities in newly diagnosed CAD patients are often reduced, thereby mitigating fitness gains because exercise work rates are below those applied to healthy populations. Novel exercise applications, historically reserved for healthy populations are now being examined within the cardiac rehabilitation setting.³ High-intensity interval training (HIIT) is among the exercise approaches recently explored in low-to-moderate risk patients with CAD. HIIT is an umbrella term for a time-efficient exercise that features cardio-based and/or multimodal exercise intervals (30 to 240 seconds) with interspersed

active or passive recovery bouts. HIIT intervals typically range from 85% to 100% of the highest heart rate attained during a peak or symptom-limited exercise test.³ HIIT has been widely adopted in healthy populations as an alternative to moderate-intensity continuous training (MICT); or the ubiquitous application of moderate intensity exercise (50% to 75% of maximal heart rate [HR_{max}]) utilized in rehabilitation settings.³ As detailed in 2 recent reviews on the topic,^{4,5} HIIT has been promulgated as an alternative exercise rehabilitation approach to MICT within cardiac rehabilitation.^{6–10} This manuscript overviews risks and benefits of HIIT for CAD patients, as evidenced in randomized controlled trials. Mitigating factors central to the HIIT risk-benefit ratio are patient compliance, safety, risk stratification, and cardiovascular outcomes. Physiologic adaptations to HIIT are weighed against the heightened risk of nonfatal and fatal cardiovascular events associated with intense exercise. Moreover, existing risk and outcome estimates are based largely on MICT prescriptions. Thus, previously undiscussed aspects of facility staffing and programmatic safety logistics are addressed relative to implementing rehabilitative HIIT.

Are There Fundamental Advantages of HIIT in Healthy Populations?

Foundational understanding of HIIT is based on evidence from healthy populations. Independent of the risks associated with high/very high intensity exercise training,

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the adaptive stimulus of HIIT is often believed to be superior to MICT. At a minimum, HIIT training in healthy populations provides equivalent or greater adaptive responses to MICT, but with a shortened time investment. For example, a HIIT regimen elicits similar improvements in aerobic capacity and body composition at a fraction of the exercise time devoted to MICT. The difference between the methods is that HIIT employs short duration intervals that approach near maximal/maximal intensity while MICT emphasizes continuous moderate intensity exercise of extended duration. In the most prominent adaptive responses to HIIT is the remarkable increase in aerobic capacity, particularly in previously sedentary patients with chronic disease.¹¹ In healthy populations, several mechanisms are believed to be responsible for improved aerobic performance, and appear to include pleiotropic stimuli such as mitochondrial biogenesis.¹²

Closely related to favorable alterations in metabolism and aerobic capacity are the influence of high intensity exercise on body mass normalization. Excess post exercise oxygen consumption is the most recognized link between exercise intensity and weight loss potential. HIIT exerts a sustained increase in post exercise oxygen consumption, often exceeding 24 hours in duration. Although metabolic responses to HIIT remain elevated when normalized for exercise duration and caloric expenditure, HIIT also has independent effects on appetite suppression. Ongoing research efforts are directed at understanding whether the HIIT benefits observed in apparently healthy populations are generalizable to clinical populations, including those with CAD.¹²

Does HIIT Outperform MICT in CAD Patients?

As an overarching conclusion, early investigations of HIIT in CAD populations are generally promising, with few conflicting outcomes.¹³ While individual HIIT protocols are too numerous to detail currently, within cardiac rehabilitation settings, most protocols adhere to a methodological convention. Of the investigations detailed currently, the most common HIIT protocol approximates a 12-week regimen with work intervals of 4 × 4 minutes in duration at an intensity of 85% to 95% HR_{max}, and 3 minutes of interspersed active recovery. Initial findings of HIIT effectiveness in these investigations, however, are tempered because few investigations have a nonexercise control group in addition to MICT and HIIT interventions.¹⁴ In the absence of a sedentary reference groups, bona fide, distinct advantages of HIIT versus MICT are difficult to resolve. Table 1 provides outcome-based comparisons between MICT and HIIT in CAD patients. Outcomes are grouped relative to maximal/submaximal exercise variables, body weight/composition, resting and exercise heart rate and blood pressure responses, selected risk factors for cardiac and metabolic disease, and cardiac performance indices. Given the lack of a sedentary control group in these investigations, the tabular comparison denotes both HIIT-MICT outcome differences in addition to whether post treatment observations were different from baseline observations.

While all the MICT-HIIT comparison categories are important rehabilitative health outcomes, perhaps none is

Table 1 Outcome comparison between HIIT and MICT for aerobic exercise performance, resting and exercise vital signs, cardiac and metabolic disease risk factors, and cardiac performance

Study lead author	VO ₂ max	Sub max exercise performance	Body weight/composition	Resting HR	Resting BP	Exercise BP	Blood glucose control	Blood lipids	Cardiac Performance
Rognmo ²⁴	HIIT* > MICT*	NR	NR	HIIT = MICT	NR	HIIT = MICT	NR	NR	NR
Warburton ⁹	HIIT* = MICT*	HIIT* > MICT*	NR	NR	NR	HIIT* = MICT*	NR	NR	HIIT* = MICT*
Amundsen ¹⁵	HIIT* = MICT*	NR	NR	HIIT = MICT	NR	NR	NR	NR	HIIT ≥ MICT
Moholdt ¹⁶	HIIT* > MICT*	NR	HIIT = MICT	HIIT* = MICT*	NR	NR	HIIT = MICT	HIIT = MICT	HIIT* ≥ MICT
Moholdt ²³	HIIT* > MICT*	NR	HIIT = MICT	HIIT = MICT*	NR	NR	HIIT = MICT	HIIT* = MICT	NR
Currie ²⁰	HIIT* = MICT*	HIIT* = MICT*	NR	HIIT* = MICT*	HIIT = MICT	HIIT = MICT	NR	NR	NR
Keteyian ⁶	HIIT* > MICT	NR	NR	HIIT = MICT	HIIT = MICT	HIIT = MICT	NR	NR	HIIT* = MICT*
Conraads ¹⁹	HIIT* > MICT*	NR	HIIT = MICT	HIIT* = MICT*	HIIT = MICT	NR	HIIT = MICT	HIIT = MICT	NR
Cardozo ¹⁴	HIIT* > MICT	NR	NR	NR	NR	HIIT = MICT	NR	NR	HIIT > MICT
Jagureguizar ¹⁰	HIIT* > MICT*	HIIT* > MICT*	NR	HIIT = MICT	HIIT = MICT	HIIT* < MICT	NR	NR	NR
Pattyn ²²	HIIT = MICT	HIIT* > MICT*	HIIT = MICT	HIIT = MICT	HIIT* < MICT*	NR	HIIT = MICT	HIIT < MICT	NR

</>/= indicates whether HIIT or MICT achieved a more desirable outcome. *Indicates a method treatment improvement over baseline values.

more relevant than aspects of cardiac performance. For this reason, it was notable that most clinically-based MICT-HIIT studies published to date do not include—by direct or indirect means—cardiac performance. Accordingly, cardiac performance variables were grouped to include metabolic (e.g., O₂ pulse) data in addition to selected findings from transthoracic echocardiographic imaging. When examined, cardiac performance outcomes were almost invariably presented as a panel of metabolic^{6,9,14} or transthoracic echocardiographic measures.^{15,16}

In regard to cardiac performance measurement panels, if HIIT were unequivocally superior to MICT, one would expect consistent improvements in cardiac performance. However, of the published investigations, only a few suggest that HIIT provides an advantage over MICT. Indeed, outcomes from previous investigations into rehabilitative HIIT urge caution in the extrapolation of findings given the isolated reports of improved cardiac function.¹⁶ Limited evidence suggests O₂ pulse may be increased in patients who underwent HIIT,¹⁴ although this finding is controversial given that other investigations reported no advantage of HIIT over MICT.^{6,9} Perhaps more consistent, echocardiographic evidence from 2 investigations suggests that ventricular compliance (evaluated by strain rate and mitral flow) is improved by HIIT training more so than MICT.^{15,16} Given that only 5 of the 11 CAD-based studies reported on cardiac performance, additional studies are needed. Moreover, current investigations provide outcomes after 4 to 16-week interventions,^{6,9,14–16} highlighting the need for extended comprehensive follow-up, that is, months-to-years postrehabilitation.

An important in-depth investigation of exercise training intensity on left ventricular function in low-risk CAD patients, using strain rate- and tissue Doppler imaging, found that most performance variables were similar between exercise intensities while early diastolic relaxation improved more in cardiac patients that engaged in HIIT.¹⁵ Whether these outcomes extend to moderate-to-high-risk patients is currently unknown, but doubtful, given projected incidence of diastolic dysfunction and recurrent cardiac events.¹⁷ Adding to the uncertainties, a recent investigation in healthy middle-aged subjects found that vascular hyperemic responses were acutely impaired by HIIT,¹⁸ which contradicts previous studies in patients with CAD, with and without heart failure, showing marked improvements in flow-mediated vasodilation after HIIT.

A consistently reported advantage of HIIT training in CAD patients is that aerobic capacity is further improved as compared with MICT interventions. Table 2 presents published increases in VO_{2peak} for HIIT and corresponding MICT groups, along with the HIIT-MICT difference for each study. Across these investigations, generally conducted for 10 to 12 weeks, both HIIT (10/10) and MICT (8/10) consistently augment aerobic capacity.^{2,9,15,17,19–22} Central to this review, 60% of these investigations report that HIIT provides an additional advantage, bolstering aerobic capacity by ~0.5 metabolic equivalent (MET; 1 MET = 3.5 ml·kg⁻¹·min⁻¹) over gains achieved by MICT.^{6,10,14,16,19,23,24} This finding, however, is tempered by the fact that VO₂ improvements are roughly equal between HIIT and MICT when

Table 2

Comparison of improved aerobic capacity in cardiac patients who underwent HIIT or MICT

Study lead author	HIIT prepost Δ (ml·kg ⁻¹ ·min ⁻¹)	MICT prepost Δ (ml·kg ⁻¹ ·min ⁻¹)	HIIT-MICT difference (ml·kg ⁻¹ ·min ⁻¹)
Rognmo ²⁴	+6.0*	+2.7*	+3.3 [†]
Warburton ⁹	+5.0*	+4.0*	+1.0
Amundsen ¹⁵	+5.0*	+4.0*	+1.0
Moholdt ¹⁶	+3.3*	+2.3*	+1.0
Moholdt ²³	+4.6*	+2.4*	+2.2 [†]
Currie ²⁰	+4.3*	+4.6*	-0.3
Keteyian ⁶	+3.0*	+0.7	+2.3 [†]
Conraads ¹⁹	+5.1*	+3.3*	+1.8 [†]
Cardozo ¹⁴	+3.8*	+0.1	+3.7 [†]
Jagureguizar ¹⁰	+4.6*	+2.5*	+2.1 [†]
Pattyn ²²	+5.2*	+4.5*	+0.7

* Indicates a treatment training effect was reported for the respective investigation.

[†] Indicates a between-group effect was reported for the respective investigation.

normalized for caloric expenditure.²⁵ Nonetheless, absolute increases in aerobic capacity benefit clinical outcomes. Based on findings from classic investigations into the prognostic value of improved VO_{2peak} in cardiac patients, the added aerobic capacity improvements observed in these studies as a result of HIIT theoretically corresponds to further 5% and 8% decreases in cardiovascular and all-cause mortality, respectively.^{26,27}

Although the long-term impact of HIIT rehabilitation in CAD patients is unknown, a few published investigations examined post-training outcomes. A 6-month follow-up of HIIT and MICT in coronary artery bypass patients revealed that aerobic capacity improved to a greater extent after HIIT.¹⁶ In contrast, Pattyn et al, conducted a 12-month follow-up after a similar HIIT-MICT multisite randomized controlled trial. One year after the respective exercise interventions, researchers observed that HIIT and MICT patients exhibited similar benefits in cardiorespiratory fitness, endothelial function, coronary risk factors, and quality of life.²² Meta-analysis indicates that HIIT in CAD patients further improves exercise capacity as compared with MICT, but the implications on morbidity and mortality are currently unknown.²⁸ While not the focus of the current review, these findings may extend to CAD patients with common co-morbidities including congestive heart failure,²⁹ diabetes and metabolic syndrome,¹¹ and possibly chronic obstructive pulmonary disease in terms of exercise adaptations as a function of training.³⁰

Is MICT Preferable to HIIT in Some Subsets of Patients With Cardiovascular Disease?

As a best practice, it is essential to consider when MICT is advantageous to HIIT. Most obviously, the well-established link that high intensity exercise may trigger life-threatening events is the focus of the next section. In addition to the heightened cardiac event risk is the consideration that MICT appears to offer comparable benefits on exercise capacity when effort is normalized for caloric

expenditure.²⁵ Importantly, these outcomes require further investigation in the form of new original science and systematic review. For example, preliminary examination of HIIT in heart failure patients suggests that total caloric expenditure supersedes relative work intensity during rehabilitative exercise.³¹

Voluntary participation in rehabilitative exercise should be in the deciding factors when counseling patients on HIIT or MICT. Importantly, most patients with atherosclerotic CAD are novice exercisers upon entry into cardiac rehabilitation. Thus, the inverse relation between high exercise intensity and programmatic adherence²¹ may affect patient retention. Moreover, high intensity exercise is gender-biased in that voluntary participation in HIIT by CAD patients was overwhelmingly male (80%),^{6,10,14–16,19,22–24} with isolated studies engaging <10% female participants.^{19,22} Supporting this observation, reports from some rehabilitation settings indicate that male cardiac patient completion rates for HIIT often exceed that of their female counterparts.¹⁹

Equally important as initial participation, adherence to exercise-based cardiac rehabilitation is central to program effectiveness. To date, 2 studies in patients with CAD reported similar compliance to HIIT and MICT, with comparably low dropout rates primarily due to poor motivation (<5%).^{19,22} Further examination of patient dropout for any medical reason was similar between MICT and HIIT (15% to 18%, respectively) for other studies involving CAD patients.^{6,16,19,22–24} Collectively, these findings suggest that early outpatient compliance is similar between the 2 training formats. Additional research is needed to fully understand the dynamics of outpatient HIIT compliance, adherence to home-based exercise is also fundamental to long term outcomes. To this end, Moholdt et al, examined self-reported adherence to home-based HIIT and found that exercise adherence was only 58%. Moreover, cardiovascular fitness improvements were tempered by the lack of a MICT control group and more so because nearly half of those assigned to the HIIT-only intervention performed MICT or combined MICT/HIIT.³² In contrast, a recent home-based investigation of MICT found that self-reported adherence rates exceeded 81% at 6 months postdischarge.³³

Aggregate findings suggest that individual receptivity to the training format is critical to the incorporation of HIIT rehabilitation. Current evidence indicates that some patients (predominately male) are more receptive to HIIT during medically supervised outpatient cardiac rehabilitation, but program compliance drops sharply when patients graduate to home-based or community settings. Given recent findings in healthy exercise participants, however, future generations of cardiac patients may exhibit increasing interest in HIIT, a time-saving alternative to MICT. In support, apparently healthy, middle aged, men and women have increasingly embraced HIIT as the preferred format for regular preventative exercise.^{34,35} Whether the high intensity "cult of exercise" common to the modern fitness industry ultimately influences future cardiac rehabilitation preferences for HIIT remains unclear and should be the focus of future research studies.

Consideration of HIIT versus MICT as the preferred physical conditioning format in CAD patients should include vascular performance outcomes. Although not fully resolved, vascular adaptations to HIIT may not be as robust in CAD patients who train at lower absolute and relative exercise intensities. Examination of HIIT-MICT comparative investigations in CAD populations reveals that changes in resting and exercise blood pressures were only evaluated in 3 studies. Of these, Warbutron et al reported similar improvements in exercise blood pressure and rate pressure product to HIIT and MICT interventions, with no change in HR_{max}.⁹ In the other 2 studies, MICT outperformed HIIT relative to exercise¹⁰ and resting blood pressure²² values, whereas absolute blood pressure values either remained unchanged or worsened in the post-HIIT subsets. Overall, ineffective blood pressure control by both MICT and HIIT interventions reflects the fact that pathological vascular remodeling is difficult to resolve once CAD is diagnosed. Modification of other cardiovascular disease risk factors including blood lipids and glucose levels appear to be only modestly impacted by both HIIT and MICT rehabilitation approaches in patients with CAD.^{6,9,15,16,19,22,23}

Supporting the notion that neither HIIT nor MICT acutely impact vascular responsiveness to training, sonographic measures of blood vessel function were largely unchanged by either exercise intensity.^{22,23} Moholdt et al, investigated indices of peripheral endothelial function after 12 weeks of HIIT or MICT and reported comparable improvements in flow mediated dilation between these exercise approaches.²³ In contrast, Pattyn et al, evaluated peripheral endothelial function before and after an identical intervention and observed no changes in vascular responsiveness to either training intensity. Not surprisingly, 1-year follow-up measures confirmed earlier negative findings.²² Disparate outcomes between the 2 studies may be due to recruitment of low-moderate risk patients in 1 study²² versus only low risk patients in the other.²³ Because HIIT and MICT elicited similar outcomes suggests that some physiologic adaptations are less robust in CAD patients, a fact that should serve as the impetus for more comprehensive examination of HIIT before concluding that it is superior to MICT.

How Risky Is HIIT in Patients With Coronary Artery Disease?

Cardiac rehabilitation professionals should consider patient safety first when deciding on HIIT incorporation. While participation in supervised cardiac rehabilitation dramatically reduces the likelihood of recurrent cardiac events, whether HIIT imposes an excessive risk for acute cardiac events in coronary patients is debatable.^{6,13} Concern is well founded in that high intensity exercise transiently elevates the risk of precipitating a cardiac event in those with known or occult CAD.³⁶ A foundational investigation of cardiovascular risk in the rehabilitation of coronary heart disease patients engaging in either high or moderate intensity exercise found that while the overall risk is low, 1 event per 58,607 patient training hours of either method, the observed rate of acute cardiac events was almost sixfold greater when performed at high intensity. Although the ~5,000 patients

referenced in this study are homogeneous for disease severity and risk stratification,⁸ additional research should resolve particulars of the HIIT stimulus in patients with CAD, metabolic disease, heart failure, varied co-morbid conditions, or combinations thereof. Moreover, patient stratification by disease type should be considered relative to HIIT rehabilitation appropriateness.

Table 3 presents a risk-stratification summary of available randomized controlled trials that compare HIIT-MICT in CAD patients,^{6,9,10,14–16,19,20,22–24} based on American Association of Cardiovascular and Pulmonary Rehabilitation criteria. Not surprisingly, no published investigations to date have recruited high risk CAD patients for HIIT rehabilitation, and the chronological progression of publication dates reflects a migration from low-to-moderate risk patient participants. Specifically, the majority of available published HIIT-MICT comparison investigations recruited low risk patients,^{9,10,14,15,23,24} while 3 examined low-moderate patients,^{19,20,22} and only 1 study examined moderate risk patients.⁶ No published studies report the occurrence of acute cardiac events, a finding that is supported by a

meta-analysis of interval training risk in CAD patients.³⁷ However, caution is reserved in extrapolating outcomes since the cumulative patient exercise hours completed for these 11 studies^{6,9,10,14–16,19,20,22–24} is a fraction of the calculated event rate of 1 of 23,182 per patient hours of intense exercise.⁸ Indeed, acute cardiac event risk and the value of direct patient supervision during exercise are highlighted anecdotally by a recent investigation of home-based, aerobic HIIT, where 1 patient died during the warmup.³²

The aforementioned observations are important to determine the ongoing risk of prescribing HIIT in cardiac populations. In addition to American Association of Cardiovascular and Pulmonary Rehabilitation risk stratification, professionals should consider patient ejection fraction, signs or symptoms of residual myocardial ischemia, threatening ventricular arrhythmias, revascularization status, plaque rupture risk, and other medical history facets³⁸ to fully gauge the safety of rehabilitative HIIT. The reader is directed to a recent publication that provides a particularly insightful delineation of exercise event criteria.¹⁰

Table 3
Comparison of HIIT and MICT for AACVPR risk stratification and untoward events

Study lead author	Patient age (years)	Sample size (n)	HIIT details	AACVPR risk stratification	Untoward events attributable to HIIT
Rognmo ²⁴	62 ± 9	17	4 × 4min 90-100%HR _{peak} , 3min active recovery, 10 weeks	Low	0
Warburton ⁹	56 ± 8	14	9 × 2min 90 HRR, 2min 40%HRR active recovery, 16 weeks	Low	0
Amundsen ¹⁵	62 ± 9	21	*3 × 3min/week MICT supplemental 4 × 4min 90-100%HR _{peak} , 3min active recovery, 10 weeks	Low	0
Moholdt ¹⁶	61 ± 7	59	4 × 4min 90%HR _{max} , 3min active recovery, 4weeks	Low	0
Moholdt ²³	57 ± 10	89	4 × 4min 90-100%HR _{max} , 3min active recovery, 12weeks	Low	0
Cardozo ¹⁴	61 ± 12	71	2min 90% HR _{peak} , 2min 60%HR _{peak} , active recovery, 16 weeks	Low	0
Jagureguizar ¹⁰	58 ± 11	72	15-30 × 20sec work _{peak} , 40 sec active recovery, 8 weeks	Low	0
Currie ²⁰	64 ± 9	14	15-20 × 1min 90%PPO, 1min 10% PPO, 12 weeks	Low-Moderate	0
Conraads ¹⁹	58 ± 9	174	4 × 4min 90-100%HR _{peak} , 3min active recovery, 12 weeks	Low-Moderate	0
Pattyn ²²	59 ± 9	163	4 × 4min 90-100%HR _{peak} , 3min active recovery, 12 weeks	Low-Moderate	0
Keteyian ⁶	59 ± 8	28	4 × 4min 80-90%HRR, 3min active recovery, 12 weeks	Moderate	1 case of resolving knee pain

Another facet of HIIT risk pertains to the potential for musculoskeletal or orthopedic injury. Given the average participant age range of 57 to 63 years in the HIIT-MICT investigations,^{6,9,10,14–16,19,20,22–24} age-dependent decreases in musculotendinous integrity may apply to habitually sedentary cardiac patients.³⁹ Nonetheless, anecdotal reports of musculoskeletal injury during HIIT rehabilitation are few.^{6,32} Meta-analysis of musculoskeletal injury in CAD patients support the low likelihood of such events,³⁷ perhaps reflecting the application of relatively low absolute workloads and common use of weight-supported methods.

Is HIIT-Based Cardiac Rehabilitation Logistically Pragmatic?

HIIT rehabilitation safety and effectiveness are limited in several ways. Although HIIT rehabilitation offers a time-saving alternative to MICT, it may pose additional barriers to regular exercise (i.e., adherence to high-intensity exercise, medical supervision needs and crash cart/automated external defibrillator access). Established MICT exercise barriers in cardiac patients include low-referral rates, suboptimal physician support, insurance coverage limitations, excessive copays, socioeconomic factors, sociodemographic factors (age, gender, race, or education level, etc.), competing time demands, low self-efficiency, transportation availability, psychosocial barriers, varied co-morbidities, and perceptions that rehabilitation is inconvenient.⁴⁰ While some barriers are rectified with patient/clinician education and alternative approaches to exercise-based cardiac rehabilitation delivery, additional evidence-based research is needed to enhance enrollment, participation, and adherence.

Staff considerations and perceptions are also central to HIIT programming and patient success. Case in point, 2 similar randomized controlled trials of HIIT-MICT provided vastly differing interpretative outcomes. Keteyian et al performed a 12-week study comparing HIIT to MICT and concluded that “HIIT could be integrated into cardiac rehabilitation.”⁶ In contrast, Conraad et al performed a comparable HIIT-MICT rehabilitation study and concluded that aerobically-based HIIT rehabilitation was “hardly

feasible.”¹⁹ While these differing conclusions cannot be resolved currently, staffing and/or facility logistics may be important. Availability of maximal cardiorespiratory testing facilities and emergency staff and equipment, as well as having classes that are dedicated to either HIIT or MICT may limit facilitation. It is also questionable whether current MICT-based staffing can support HIIT-based rehabilitation classes.⁶ Self-selection for HIIT or MICT may also preclude patient participation if schedule conflicts exist.

Conclusion

While high intensity exercise precipitates acute cardiac events ~6-times more frequently than moderate workloads,⁸ comparisons of HIIT and MICT via randomized control trials indicates the absolute risk for cardiovascular events and musculoskeletal injury remain low. One factor is that most published investigations of HIIT utilize low risk cardiac patients. Nonetheless, correct application of HIIT does appear to offer some advantages over MICT, as detailed in Figure 1. Based on existing evidence, the “ideal” HIIT patient is in their 50s to 60s or younger, exhibits low-risk criteria, normal left ventricular function, aerobic capacity >7 METs, stable coronary disease, and the absence of signs and/or symptoms for residual myocardial ischemia or threatening ventricular arrhythmias. Somewhat problematic of these research findings, however, men are 5 times more likely to participate in HIIT, and adherence to HIIT drops significantly outside of medical supervision.

With regard to the contemporary rehabilitation setting, there is no consensus regarding staffing approaches and HIIT logistics. Based on varied health and performance outcomes, HIIT offers CAD patients some aerobic fitness training stimulus advantages as compared with MICT. In contrast, alterations in cardiac function and cardiovascular disease risk factor modification appear to be modest and comparable to MICT. Collective understanding warrants caution in HIIT implementation in conventional rehabilitation programs. Additional long-term studies should assess safety, compliance, and morbidity and mortality following HIIT. HIIT applications in nonmedically supervised settings should also be addressed.

HIIT-MICT comparison for short-term rehabilitation outcomes		
HIIT = MICT	HIIT > MICT	HIIT < MICT
<ul style="list-style-type: none"> Resting HR Resting/Exercise BP Body composition Blood glucose control Blood lipid modification 	<ul style="list-style-type: none"> VO₂max Sub-maximal exercise performance Cardiac performance (possibly) 	<ul style="list-style-type: none"> Unsupervised exercise adherence

Figure 1. A comparative summary of short-term outcomes following HIIT versus MICT approaches in cardiac rehabilitation patients with coronary artery disease. HIIT and MICT approaches yield similar unchanged (normal font) outcomes for cardiovascular disease risk factor modification. Similarly, adherence to inpatient exercise programming is similar for HIIT and MICT regimen. MICT appears to be advantageous (bold font) to HIIT when considering unsupervised exercise adherence. Short-term exercise performance advantages, and perhaps cardiac performance outcomes, are improved slightly after HIIT interventions as compared with MICT.

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