Original Article

JHSMR Journal of Health Science and Medical Research

Effect of Metabolic Equivalent-Based Bicycle Ergometer Exercise Training on Functional Outcomes in Phase I Cardiac Rehabilitation: A Non-Randomized Controlled Trial

Nandhini Priya, MPT, Senthil Kumar Thillai Govindrajan, Ph.D., Ajith Kumar Pichai, MPT, Sridevi S, MPT, Natrajan Venkatesh, Ph.D.

Department of Cardiopulmonary Physiotherapy, Sri Ramachandra Faculty of Physiotherapy, SRIHER (DU), Chennai 600116, Tamil Nadu, India.

Received 26 December 2024 • Revised 21 May 2025 • Accepted 4 June 2025 • Published online 29 October 2025

Abstract:

Objective: Patients undergoing cardiac surgery often experience impaired physical activity and exercise capacity. Safety concerns, including anxiety and fear of unsupervised walking, limit optimal exercise training in the early phase. Metabolic equivalent-based (MET) bicycle ergometer training is another option with quantifiable measures for early exercise training. The unexplored benefits of such training warranted this study. We aimed to compare its efficacy with traditional care in phase I cardiac rehabilitation among a post-cardiac surgery population.

Material and Methods: In this non-randomized controlled trial, eligible subjects were patients who had undergone adult cardiac surgeries, such as Coronary Artery Bypass Grafting and Valve Replacement, of both genders, aged 30-70 years, with an LVEF greater than 50%, and an uncomplicated postoperative period. Subjects were allocated either to the control or study group. Subjects with high cardiac risk and musculoskeletal and neurological dysfunction were excluded. The study and control groups received MET-based bicycle ergometer training and routine hospital care, respectively. Functional capacity and Left Ventricular Ejection Fraction were measured before and after training. Physiological response was monitored before, during, and after training in all subjects.

Results: Thirty patients completed the trial (15 in each group), with 5 dropouts in each group. Baseline characteristics were similar. Physiological response during MET-based exercise was found to be within safe limits. Functional capacity improved significantly in the study group (228.2m) compared with the control group (74m), with a p-value<0.001. Improvement in Left Ventricular Ejection Fraction was significant in both groups.

Contact: Senthil Kumar Thillai Govindrajan, Ph.D.
Department of Cardiopulmonary Physiotherapy, Sri Ramachandra Faculty of Physiotherapy, SRIHER (DU), Chennai 600116, Tamil Nadu, India.
E-mail: senthilkumar.t@sriramachandra.edu.in

J Health Sci Med Res 2026;44(3):e20251273
doi: 10.31584/jhsmr.20251273
www.jhsmr.org

Conclusion: MET-based bicycle ergometer training was found to be feasible, safe, and had a clinically significant impact on functional capacity.

Keywords: cardiac rehabilitation, coronary artery bypass grafting, functional capacity, metabolic equivalents, valve replacement

Introduction

Non-communicable disease (NCDs) mortality represented as 72.3% globally, cardiovascular disease (CVD) combined with cerebrovascular accidents (CVA), accounts for an 85.1% increase in societal burden.[1] Benefits of exercise-based Cardiac Rehabilitation have been established for improvements in the physical function, clinical measures of health, and health-related quality of life (HRQoL), and have also been shown to reduce all-cause mortality in patients with CVD. Cardiac Rehabilitation requires a reengineering of traditional models due to decreased applicability and feasibility. MET-based models of care, utilized with modification according to individual needs without compromising the standards of care, are highly appreciated.[2] CR provides major secondary prevention to the participants, with pertinence to an optimal aerobic intensity implementation of 45% VO2R/60%HRmax[3].

Physical activity performed at a sufficient level brings glycemic control, fat mass distribution, and cardiovascular risk factors under control, along with enhanced aerobic capacity and exercise volume[4]. In the early phases of Cardiac Rehabilitation (CR), metabolic equivalent (MET)-based training is routinely utilized to describe the functional capacity of an individual, and to provide a repertoire of activities ensuring safety in practice[5]. VO2 max is the maximum amount of oxygen utilization, while performing high-threshold activities involve large groups of muscles, expressed in MET[6]. Measurement of MET can predict the overall outcome of patients, and can also be utilized as a training method and outcome measure[7].

The exploration of bicycle ergometer with MET-based training is sparsely reported research literature. Predetermined MET values are used in exercise training post-myocardial infarction, whereas in post-cardiac surgery status, MET-based management has not been documented.

The Stationary bicycle ergometer has not been effectively utilized, but it has been considered as an alternative in phase I cardiac rehabilitation. The standard care routinely follows the protocol for achieving daily needs and enhancing recovery from any postoperative physical impairments. Whereas managing patients using MET-based management with a stationary bicycle ergometer serves as a quantifiable measure towards recovery in post-operative early cardiac rehabilitation.

The use of a bicycle ergometer in phase II cardiac rehabilitation is evidence that supports its effectiveness; however, use in phase I has been limited. Hence, this study aimed to compare the effects of MET-based bicycle ergometer exercise training with routine care during phase I on the improvement of functional capacity after cardiac surgeries undertaken to explore the utility and feasibility of metabolic equivalent-based training.

Material and Methods

Study design and sampling

A prospective non-randomized controlled trial was approved by the Institutional Ethics Committee (CSP/18/SEP/73/268).

Sampling: The convenience sampling method was followed.

Participants were allocated into groups of 20, with a dropout of 5 in each group, to obtain the mean difference of 50 meters between the groups by the 6MWT with powers of 80% and 95% CI levels, based on previous studies[7].

Participants and intervention

Inclusion Criteria: Adults after cardiac surgery, including Coronary Artery Bypass Grafting (CABG) and Valve Replacement, were screened for eligibility criteria. Both genders, 30-70 years of age, low-risk patients with LVEF >50% with uncomplicated postoperative periods were included. Exclusion criteria: Individuals with physical limitations (orthopedic and/or neurological disorders), cardiac arrest survivors, hemodynamic instability, INR<1 or >3, post-surgical cardiac arrhythmia, and high-risk patients (as per AACVPR and AHA guidelines) were excluded. Participants were recruited after agreeing to participate in wards following routine physiotherapy care (PT care) in the Intensive Care Unit. Data acquisition was completed on demographic characteristics; 1st, 4th, and 8th sessions assessments.

Procedure

Control group: Participants in the control group received hospital routine care as per the standard of practice, which includes airway clearance and graded ambulation with precise pre- and post-recovery vital monitoring within the hospital corridors.

Study group: Participants received routine care and bicycle ergometer exercise for 10-20 minutes till the day of discharge. Initially, participants were familiarized with the bicycle ergometer, then gradually encouraged to perform a continuous metabolic equivalent-based exercise training program. The goal of bicycle pedaling was 10-15 minutes steady. However, depending on the participant's effort tolerance, the 1st session was intermittently paused as needed by the participant. The load was applied as per the participant's tolerance level and comfort in order to achieve steady self-paced pedaling. Gradually, participants were encouraged to do continuous pedaling with metabolic equivalent-based training for a minimum of 6 to 8 sessions till the day of discharge (twice a day).

Initially, the MET level was calculated on free-load pedaling. The MET during the initial exercise training was 1.5- 2 METs. Gradually, it was increased by 0.5 METs from the second session. The MET was increased by increasing the resistance (in watts) of pedaling. The load was gradually increased every session so as to attain a MET level of more than 5 METs before discharge, as per the tolerance of participants. As per the ACSM guidelines, the MET calculation was done using the leg ergometer formula[8].

Leg ergometer formula

VO_2=(10.8 × watts) / Mass (weight in kg)+(7)

MET=Vo_2 /3.5ml/kg/min

Outcome measures

Socio-demographic variables such as gender, age, and occupational history were collected for the study. Anthropometric measurements (BMI) and surgical details were also collected. A participant's clinical condition in the postoperative period and any comorbidities (diabetes mellitus, hypertension, smoking, alcohol use) were noted. Primary outcomes such as functional capacity using the 6-Minute Walk test and Left Ventricular Ejection Fraction (LVEF) were measured at the baseline (study induction) and before discharge, after the training period (6-8 sessions of training).

Statistical analysis

Statistical analysis was conducted using JASP software version 0.9. Normality of the data was assessed with the Kolmogorov-Smirnov test. A parametric test was applied to all available data. Categorical variables are reported as numbers and percentages. Continuous variables are presented as means and standard deviations.

Demographic data were analyzed using the Chi-squared test. Within-group comparisons of the outcome measures, before and after the training, were performed with a paired t-test. The comparison between the groups was done using the independent samples t-test. A p-value less than or equal to 0.05 was considered statistically significant. Additionally, in the given sample, the functional capacity was compared among the diabetic population.

Results

Thirty patients who underwent cardiac surgeries (CABG and Valve Replacement) were included in the study; 15 participants in the control group and 15 in the study group were included for analysis, as in Figure 1. All numerical values in the tables were expressed as a mean (standard deviation) unless otherwise specified.

Table 1 The mean age was higher in the study group than in the control group, and the sample consisted predominantly of males. In this study, we found that there was a greater number of CABG (86.7%) than valve replacement subjects. In both groups, CABG was higher than valve replacement. The differences in these parameters were not statistically significant, indicating that the groups were similar at the beginning of the study.

Table 2 illustrates the comparison of physiological responses between the 2 groups before and after training. The mean value of resting HR and Peak HR was found to be decreased on the final day of the training sessions compared to the first day, but the difference was statistically insignificant (p-value>0.05). The RPE was slightly increased

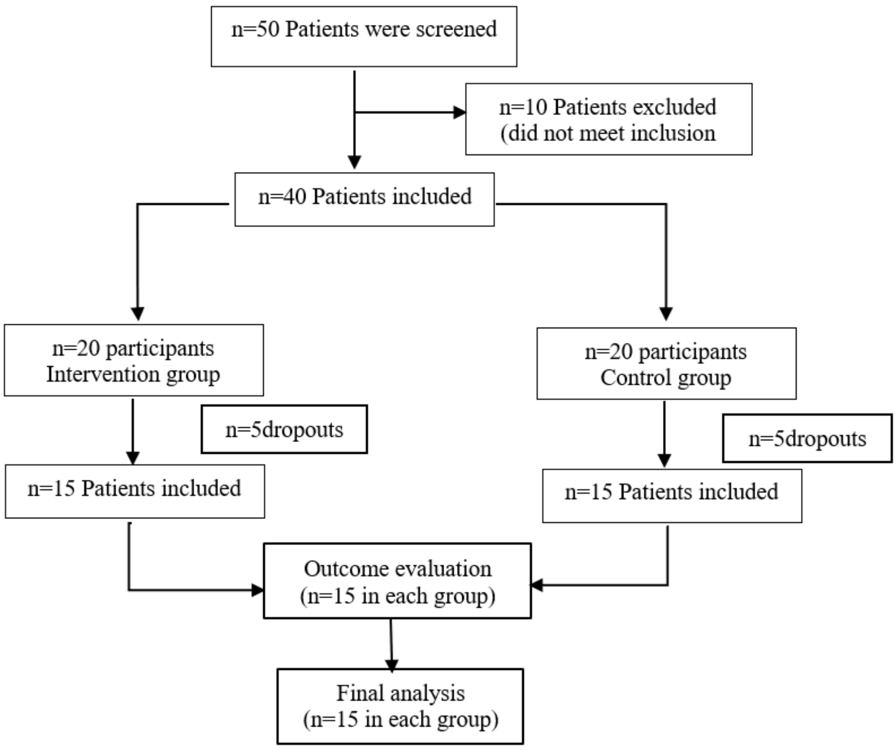

Figure 1 Participant flowchart

Table 1 Characteristics of the study participants

	Control group n=15	Study group n=15	Total	p-value*
Age (years) Mean (S.D.)	54.27(15.54)	56.67(6.032)	55.47	0.72
BMI (kg/m$^{2)}$ Mean (S.D.)	25.83(3.58)	26.58(3.25)	26.21	0.96
Gender (%)				
Male	11(73.3)	12(80)	23	0.44
Female	4(26.7)	3(20)	7	
Comorbidities (%)				
Diabetes	13(86.7)	13(86.7)	26	0.61
Hypertension	13(86.7)	13(86.7)	26	0.61
Smoking	5(33.3)	7(46.7)	12	0.31
Type of surgery (%)				
CABG	11(73.3)	13(86.7)	24	0.153
Valve replacement	4(26.7)	2(13.3)	6	-

BMI=body mass index, CABG=coronary artery bypass grafting, mean (S.D.)- mean (standard deviation), kg/m2=kilograms/ square meter, p-value*- Independent - t ‘test

Table 2 Comparison of physiological responses between control and experimental groups

		Control group (n=15)	Study group (n=15)	p-value*
Resting HR	Pre test	93.87 (10.49)	95.6 (11.7)	0.67
	Post test	89.67 (7.71)	90.53 (11.06)	0.80
Peak HR	Pre test	102.6 (9.62)	108.1 (11.79)	0.17
	Post test	100.1 (8.37)	99.07 (12.99)	0.80
MAP	Pre test	99 (5.55)	95.55 (4.11)	0.06
	Post test	96.22 (3.30)	95.78 (4.07)	0.74
RPP	Pre test	13217 (1153)	13,3627 (1301)	0.74
	Post test	12614 (1223)	12,225 (1737)	0.48
RPE	Pre test	6.1 (0.35)	6(0)	**0.05**
	Post test	6.5 (0.51)	6.2(0.45)	0.14

HR=heart rate; map-mean arterial pressure, RPP=rate pressure product, RPE=rating of perceived exertion, p-value*-Independent -t test; Level of Significance p-value<0.05, data are expressed in mean (standard deviation)

in post-training in both groups, but the difference was statistically insignificant (p-value 0.146) in the posttest.

Table 3 It was observed that the HR, SBP, DBP, and SPO2 remained within the safe zone. The HR was reduced from a mean value of 95.6 to 90.53 at rest. A similar trend was found at the peak and during recovery, which indicates the safe zone of training during metabolic-based bicycle ergometer training, as well as parasympathetic stimulation.

Table 4 The mean value of HR, SBP, and SPO2 was found to be decreased on the final day of training in comparison to the first day. The difference was statistically insignificant. The change in DBP (Table 4) was found to be significant.

Table 3 Physiological responses during MET–based bicycle ergometer exercise training

	HR			SBP			DBP			SPO2			RR			RPE		
	Sessions			Sessions			Sessions			Sessions			Sessions			Sessions		
	1st	4th	8th	1st	4th	8th	1st	4th	8th	1st	4th	8th	1st	4th	8th	1st	4th	8th
At rest	95.6 (11.7)	93.60 (10.61)	90.53 (11.06)	116.3 (6.67)	116.3 (6.67)	116.0 (5.07)	78 (5.60)	78 (5.60)	78.0 (4.14)	96.6 (1.50)	96.6 (1.50)	97.2 (1.56)	26.93 (7.78)	25.2 (6.62)	25.4 (4.76)	6 (0)	6 (0)	6 (0)
At peak	108.1 (11.79)	106 (11.6)	99.07 (12.99)	124 (6.325)	124 (6.32)	123.3 (4.88)	81.33 (3.51)	81.33 (3.51)	82.0 (4.14)	94.33 (2.46)	94.33 (2.46)	95.07 (3.01)	32.67 (6.34)	30.3 (6.04)	30.07 (4.14)	8.4 (0.50)	8.4 (0.50)	8.40 (0.91)
At recovery	100.5 (12.79)	97.73 (13)	91.4 (10.69)	114.3 (5.62)	114.3 (5.62)	116.0 (5.07)	77.33 (5.93)	77.33 (5.93)	78.6 (3.51)	96.13 (1.59)	96.13 (1.59)	98.8 (2.04)	28.4 (6.01)	26.13 (6.34)	26.53 (4.40)	6.6 (0.72)	6.6 (0.72)	6.2 (0.45)

HR–Heart Rate, SBP=systolic blood pressure, DBP=diastolic blood pressure, SPO2–oxygen saturation, RR=respiratory rate, RPE–rating of perceived exertion, data are expressed in mean (standard deviation)

Table 4 Comparison of mean difference in physiological parameters during MET-based bicycle ergometer exercise training

Variables	1st day	8th day	Mean difference	p-value*
HR	12.46 (8.42)	8.53 (5.12)	3.93	0.16
SBP	7.66 (4.169)	7.33 (4.57)	0.33	0.67
DBP	3.33 (4.88)	4 (5.071)	0.66	**0.01**
SPO2	-2.26 (2.764)	-2.13 (3.27)	4.4	0.89

SpO2=oxygen saturation, HR-heart rate, DBP=diastolic blood pressure, p-value*=Independent-t test, SBP=systolic blood pressure, data are expressed in mean (standard deviation)

Table 5 Comparison of functional capacity between study and control groups

Group (6MWT)	Pre-Training	Post Training	Mean Difference	p-value*
Control Group (n=15)	147.3(66.6)	221.3(67)	74	**<0.001**
Study Group (n=15)	145.1(62.2)	373.3(76.)	228.2	**<0.001**
Mean Difference	2.2	152	-	-
p-value**	0.926	**<0.001**	-	-

p-value*-Unpaired -t'test; p - value**-Independent -t' test; data are expressed in mean (standard deviation), 6MWT=6 Minute Walk Test

Table 5 Comparison of functional capacity before and after training in both groups showed an increase in 6MWD in both groups, with longer distances walked by the study group compared to the control group (p-value<0.001). Pre- and post-change in functional capacity within both groups were statistically significant (p-value<0.001).

LVEF was analyzed before and after training in both groups and found to be increased in both groups. The mean value was 55.6 in the control group and 58.2 in the study group, with a p-value of 0.15.

Figure 3 shows that the functional capacity in coronary artery bypass grafting surgery was greater in the study group (373.08m) than the control group (215.5m), and it was insignificant (p-value>0.212), whereas within groups, it was significant in both groups (p-value<0.001).

Functional capacity in valve replacement patients was insignificant between the groups, whereas it was significant within the group. However, the study group showed more when compared to the control group, with a mean value of 237.5m in the control group and 375m in the study group.

Discussion

Despite diverse managing methods in practicing CR, the present study concentrated on the application of MET-based bicycle ergometer exercise programs in comparison with the routine hospital management in order to achieve the functional outcomes, as discussed in the Results. In this study, the use of bicycle ergometers among cardiac surgery patients proved to be a safe and feasible exercise tool. On the comparison of functional capacity between diabetes patients in both groups, there was a significant difference in the diabetic population between the groups, and also within both pre- and post-training. Functional

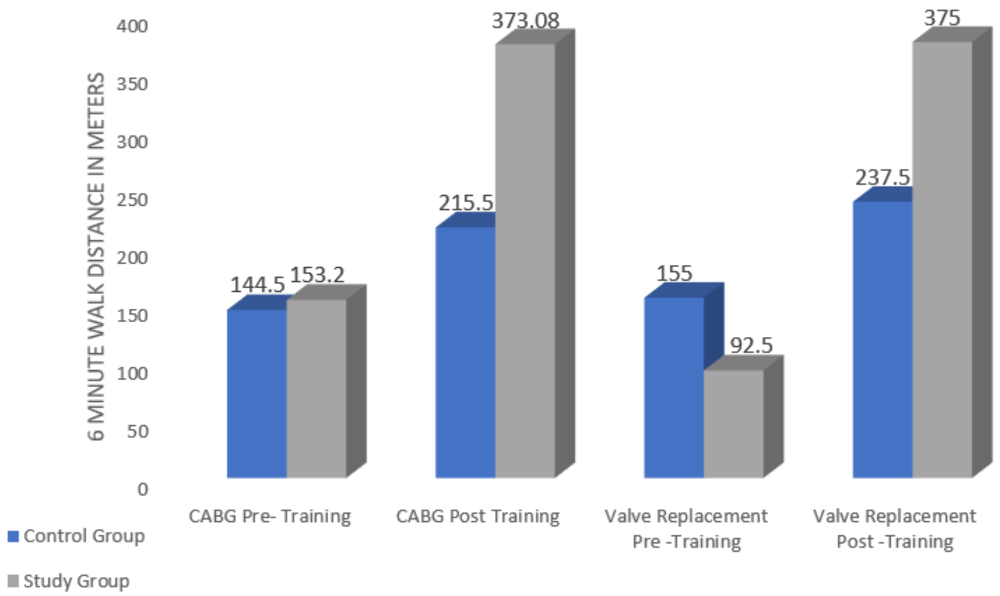

Figure 2 Comparison of left ventricular ejection fraction between study and control groups

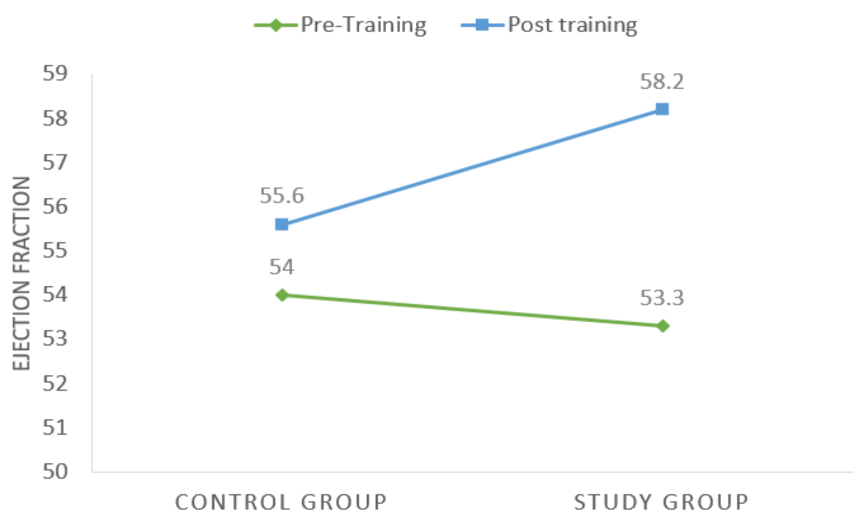

Figure 3 Comparison of functional capacity among coronary artery bypass grafting surgery in both groups and among valve replacement in both groups

capacity in the diabetic population was higher in the study group than control group. The mean value in the control group was 223.1m; the study group was 379.2m with a p-value<0.001, which is statistically significant. Functional capacity among CABG and valve patients showed an insignificant difference between the groups in both pre- and post-training (p-value>0.227), whereas both groups had significance within groups (p-value<0.001). The functional capacity was higher in coronary artery bypass grafting surgery than in valve replacement surgery; the mean value in coronary artery bypass grafting was 306.5m and in valve replacement, 237.5m.

Bicycle ergometer feasibility towards cardiac surgery

A trial on older individuals after valve surgery or an intervention resulted in greater improvements in their functional capacity and muscle strength with the successful application of cardiac rehabilitation bicycle ergometer as an intervention. And, in another randomized controlled trial on heart failure patients using the bicycle ergometer in the early phase, as in our study, there were significant improvements observed in functional capacity, balance, and strength of the quadriceps muscles among the participants.

The bicycle can facilitate continuous, prolonged mobilization and allow appropriate control of duration and intensity. That can be adjusted based on participants' effort tolerance and MET achieved in comparison with the previous day's physiological responses to exercise. Our results showed a significant improvement in the functional capacity (6MWD), LVEF, and improvements in exercise duration and reduction of cardiopulmonary stress.

Phase I CR on functional capacity

An improvement in the functional capacity in both groups after incorporating the phase I cardiac rehabilitation protocol among the participants was noted. CR must include medical management, psychosocial counselling, and physical activity promotion that can prevent the secondary complications[9]. The study group showed a superior trend of increased 6MWD where the participants received a metabolic equivalent-based cycle ergometer. A non-randomized single-blinded trial on coronary artery bypass grafting patients resulted in enhanced recovery and improved 6MWD with effective implementation of phase I cardiac rehabilitation. Furthermore, the study group allowed participants to be monitored continuously for cardio-respiratory variables during the CR program, where the exercise intensity showed better improvement. Previous studies have reported that early phase I exercise training with a cycle ergometer improved quadriceps strength and functional capacity (6MWD)[10,11].

Bicycle ergometer: a simple and effective alternative tool

The goal of using alternative gadgets in the rehabilitation protocol by using a MET-based bicycle ergometer in the early phase of the post-operative period was to increase functional capacity. A systematic review evaluated the 13 studies that showed a significant improvement for participants in their recovery; among those studies, the bicycle ergometer was an effective and viable strategy for people with difficulties enrolling in physical rehabilitation programs. The use of bicycle ergometer training in replacing walking has the potential to reduce the risk of falling, improve systemic circulation, improve exercise intensity, and improve exercise training frequency, along with the monitoring of vital signs at the metabolic demand peak during training sessions[12,13]. A study has shown that cardiac responses to light bicycle ergometer exercise maintained hemodynamic and vascular responses[14]. Another review expressed that a linear relationship existed between exercise and its benefits, irrespective of the nature of the exercise utilized[15].

Remote cardiac rehabilitation – about the bicycle ergometer

From the present study, the safety and efficacy of using the MET-based bicycle ergometer training were statistically significant in improving functional outcomes. Henceforth, an alternate source for CR worldwide is trending towards remote cardiac rehabilitation, where the utility of a bicycle ergometer with predetermined exercise intensity would be safe for practice at remote set-up sites, which is an eye-opening scenario from this study[7]. However, economic constraints might act as a barrier, with vulnerability towards exercise-induced adverse reactions[16]. Tackling such adverse reactions from exercise requires telemonitoring support, such as telemetry electrocardiogram, wearable heart rate monitors, accelerometers, and pedometers[17 -18].

Effects on clinical parameters

There were clinically significant decreases in resting HR and dyspnea values in both groups after phase I CR training in our study. The Mean participant RPE level was at 6, and during the peak level at 8, indicating a safe zone and mean values for all parameters within the safer limits during training (Table 3). Our study proves that phase I CR improves hemodynamic responses, sub-maximal work tolerance through reducing cardiac work, and myocardial oxygen demand. The enhancement of HR and RPE was elicited during the physical conditioning of patients with cardiovascular diseases using MET[5,19]. Systematic reviews reported significant improvements in HR reserve after CR among participants when monitored for exercise intensity and duration of training[20,21].

Effects on diabetes

This study also showed an improvement in the functional capacity of the diabetic population. Thus, the effect of this training program is profound among the diabetic population. Probably these exercises are improving insulin dynamics, which would help improve oxygen extraction, leading to increases in functional capacity[22-23]. Differences in functional capacity between diabetics and non-diabetics, as a whole in the study, were not statistically significant. No matter, the generalization of this study could not be done, as the sample size was too small in non-diabetics (n=4) (diabetics (n=26)).

Study limitations

This was a single-center trial with limited subjects. Future multi-centered trials with a larger sample could shed light on the functional outcomes before the generalization of the results. The long-term benefits of bicycle ergometer training were not explored, as this study was limited to phase I CR[18]. Even though MET was measured using standardized formulae and calibrated equipment, its validity may not be equivalent to that of the metabolic cart. Future studies warrant assessing the long-term benefits of such training and utilizing the validated tool of MET measurements.

Conclusion

The global practice of CR was limited due to various constraints, including economics, feasibility, and safety, and thus, an alternative approach was required in order to implement effective training for achieving enhanced functional outcomes[24]. The study group improved clinically and statistically in functional capacity at a higher rate than the control group, indicating the effectiveness of MET-based training using a bicycle ergometer after cardiac surgeries. The changes in physiological variables were within safe training zones, and no adverse events occurred during MET-based bicycle ergometer training, showing its safety and feasibility in early-phase I CR training.

Conflicts of interest

No conflicts of interest declared.

References

1. Naghavi M, Abajobir AA, Abbafati C, Abbas KM, Abd-Allah F, Abera SF, et al. Global, regional, and national age-sex specific mortality for 264 causes of death, 1980–2016: a systematic analysis for the global burden of disease study 2016. Lancet 2017;390:1151–210.
2. Fletcher GF, Balady GJ, Amsterdam EA, Chaitman B, Eckel R, Fleg J, et al. Exercise standards for testing and training: a statement for healthcare professionals from the American Heart Association. Circulation 2001;104:1694-740.
3. Abell B, Glasziou P, Hoffmann T. The contribution of individual exercise training components to clinical outcomes in randomised controlled trials of cardiac rehabilitation: a systematic review and meta-regression. Sports Med Open 2017;3:19. doi: 10.1186/s40798-017-0086-z.
4. Vanhees L, Geladas N, Hansen D, Kouidi E, Niebauer J, Reiner Ž, et al. Importance of characteristics and modalities of physical activity and exercise in the management of cardiovascular health in individuals with cardiovascular risk factors: recommendations from the european association of preventive cardiology (Part II). Eur J Prev Cardiol 2012;19:1005-33.
5. Jetté M, Sidney K, Blümchen G. Metabolic equivalents (METS) in exercise testing, exercise prescription, and evaluation of functional capacity. Clin Cardiol 1990;13:555–65.
6. Swain DP, Franklin BA. Is there a threshold intensity for aerobic training in cardiac patients? Is there a threshold intensity for aerobic training in cardiac patients? Med Sci Sports Exerc 2002;34:1071-5.
7. Trevisan MD, Lopes DGC, de Mello RGB, Macagnan FE, Kessler A. Alternative physical therapy protocol using a cycle ergometer during hospital rehabilitation of coronary artery bypass grafting: A clinical trial. Braz J Cardiovasc Surg 2015;30:615–9.
8. Glass S, Dwyer GB, American College of Sports Medicine ACSM'S metabolic calculations handbook. Philadelphia: Lippincott Williams & Wilkins; 2007.
9. Piepoli MF, Corrà U, Benzer W, Bjarnason-Wehrens B, Dendale P, Gaita D, et al. Cardiac rehabilitation section of the european association of cardiovascular prevention and rehabilitation. Secondary prevention through cardiac rehabilitation: from knowledge to implementation. a position paper from the cardiac rehabilitation section of the european association of cardiovascular prevention and rehabilitation. Eur J Cardiovasc Prev Rehabil 2010;17:1-17.
10. Borges DL, Silva MG, Silva LN, Fortes JV, Costa ET, Assunção RP, et al. Effects of aerobic exercise applied early after coronary artery bypass grafting on pulmonary function, respiratory muscle strength, and functional capacity: a randomized controlled trial. J Phys Act Health 2016;13:946–51.
11. Pattanshetty RB, Sinai Borkar S, Khetan SM. Access this article online. Int J Physiother Res 2014;2:669–76.
12. Burtin C, Clerckx B, Robbeets C, Ferdinande P, Langer D, Troosters T, et al. Early exercise in critically ill patients enhances short-term functional recovery. Crit Care Med 2009;37:2499–505.
13. Camila Moura Dantas1 PF dos SS, FHT de S, RMFP, SM, CM, MC de OCG de A. Dantas CM, Silva PF, Siqueira FH, Pinto RM, Matias S, Maciel C, Oliveira MC, Albuquerque CG, Andrade FM, Ramos FF, França EE. Influence of early mobilization on respiratory and peripheral muscle strength in critically ill patients. Rev Bras Ter Intensiva 2012;24:173-8.
14. Atsuhiko Matsunaga, phd, et al. Adaptation to low-intensity exercise on a cycle ergometer by patients with acute myocardial infarction undergoing phase I cardiac rehabilitation. Circ J 2004; 68:938-45.
15. Sagar VA, Davies EJ, Briscoe S, Coats AJ, Dalal HM, Lough F, et al. Exercise-based rehabilitation for heart failure: systematic review and meta-analysis. Open Heart 2015 28;2:e000163.
16. Mbau L, Mallya Prabhakar P, Khan Z. Effectiveness of cardiac rehabilitation services in low- and middle-income countries: a systematic review. Cureus 2023;15:e50953.
17. Li X, Zhao L, Xu T, Shi G, Li J, Shuai W, et al. Cardiac telerehabilitation under 5G internet of things monitoring: a randomized pilot study. Sci Rep 2023;13:18886.
18. Antoniou V, Kapreli E, Davos CH, Batalik L, Pepera G. Safety and long-term outcomes of remote cardiac rehabilitation in coronary heart disease patients: a systematic review. Digit Health 2024;10:20552076241237661.
19. El-Malahi O, Mohajeri D, Mincu R, Bäuerle A, Rothenaicher K, Knuschke R, Rammos C, Rassaf T, Lortz J. Beneficial impacts of physical activity on heart rate variability: a systematic review and meta-analysis. PLoS One 2024;19:e0299793.
20. Gebremichael LG, Champion S, Nesbitt K, Pearson V, Bulamu NB, Dafny HA, et al. Effectiveness of cardiac

rehabilitation programs on medication adherence in patients with cardiovascular disease: a systematic review and meta-analysis. Int J Cardiol Cardiovasc Risk Prev 2023;20:200229.

21. Snoek JA, Van Berkel S, Van Meeteren N, Backx FJG, Daanen HAM. Effect of aerobic training on heart rate recovery in patients with established heart disease: a systematic review. PLoS One 2013;8:e83907.
22. Anderson TJ, Grégoire J, Pearson GJ, Barry AR, Couture P, Dawes M, et al. 2016 Canadian cardiovascular society guidelines for the management of dyslipidemia for the prevention of cardiovascular disease in the adult. Can J Cardiol 2016;32:1263-82. doi: 10.1016/j.cjca.2016.07.510.
23. Dinakar S, Sridevi S, Professor A. A study to find the correlation between six-minute walk distance and blood glucose level in diabetic patients. Int J Physiother Res 2015;3:1099–103. doi: 10.16965/ijpr.2015.150.
24. Wang L, Liu J, Fang H, Wang X. Factors associated with participation in cardiac rehabilitation in patients with acute myocardial infarction: a systematic review and meta-analysis. Clin Cardiol 2023;46:1450-7.