RESEARCH PAPER

Impact of Structured Exercise Training on Blood Pressure and Heart Rate Recovery in Post–Coronary Artery Bypass Grafting Individuals

Dr Chandrakant Babaso Patil[1*], Dr V.C. Patil[2]

[1]PhD Scholar, Associate Professor, Krishna College of Physiotherapy, Krishna Vishwa Vidyapeeth (Deemed to be University), Karad – 415110
[2]Professor, Krishna Institute of Medical Sciences, Krishna Vishwa Vidyapeeth (Deemed to be University), Karad – 415110

***Corresponding Author:** Dr Chandrakant Patil
*Email id: chandupatil69@gmail.com.

Received: 20th Feb, 2026 | **Revised:** 4th Mar, 2026 | **Accepted:** 25th Mar, 2026 | **Available Online:** 10th Apr, 2026

Abstract
Background: Coronary artery bypass grafting (CABG) is associated with postoperative cardiovascular and autonomic dysfunction, including impaired blood pressure regulation and delayed heart rate recovery (HRR), both predictors of adverse cardiovascular outcomes [1–3]. Early structured exercise may enhance physiological recovery.
Objective: To evaluate the impact of structured exercise training on blood pressure and HRR in post-CABG individuals.
Methods: A prospective, parallel-group randomised controlled trial was conducted among 98 post-CABG patients (49 per group). Participants were randomised to structured exercise or conventional rehabilitation. The intervention was administered from postoperative day 3 to day 15 (13 days). Outcomes included systolic blood pressure (SBP), diastolic blood pressure (DBP), and HRR. Statistical analysis included paired t-tests, independent t-tests, chi-square tests, and ANCOVA with Cohen's d effect sizes.
Results: HRR improved significantly in the intervention group (mean increase +8 bpm; $p < 0.001$; Cohen's $d = 0.90$). Between-group differences in SBP and DBP showed favourable trends in the intervention group; however, these did not reach statistical significance ($p = 0.489$ and $p = 0.154$, respectively).
Conclusion: Early structured exercise significantly improves autonomic recovery following CABG, as evidenced by markedly improved HRR. Trends toward improved blood pressure regulation warrant further investigation with longer follow-up periods.

Keywords: CABG; systolic blood pressure; diastolic blood pressure; structured exercise; heart rate recovery; cardiac rehabilitation.

How to cite this article: Patil CB, Patil VC. Impact of Structured Exercise Training on Blood Pressure and Heart Rate Recovery in Post–Coronary Artery Bypass Grafting Individuals. Int J Drug Deliv Technol. 2026;16(4):580-585. DOI: 10.25258/ijddt.16.4.61

1. Introduction

Coronary artery bypass grafting (CABG) is a widely performed surgical intervention for coronary artery disease, significantly improving survival and quality of life [1, 4]. However, postoperative recovery is often complicated by impaired cardiovascular regulation, including elevated blood pressure and delayed autonomic recovery [2, 3].

Heart rate recovery (HRR), defined as the reduction in heart rate following cessation of exercise, is a well-established marker of autonomic nervous system function, particularly parasympathetic reactivation. Impaired HRR has been associated with increased cardiovascular mortality and poor prognosis [2, 14].

Exercise-based cardiac rehabilitation has been shown to improve cardiovascular outcomes, including blood pressure control and autonomic regulation [5–7]. Multicomponent exercise programs combining aerobic and resistance training have demonstrated superior benefits compared to conventional rehabilitation approaches [6, 10].

Despite these benefits, early-phase rehabilitation remains underutilised in clinical practice, particularly in rural populations with limited access to specialised cardiac rehabilitation services [8, 9]. Few studies have evaluated multicomponent exercise protocols initiated within 72 hours post-CABG in rural, resource-limited settings — a gap this study aimed to address. Therefore, the present study evaluated the effect of early structured exercise training on blood pressure and HRR in post-CABG individuals.

2. Materials and Methods

2.1 Study Design and Setting

A prospective, parallel-group randomised controlled trial was conducted over a 13-day intervention period in

*Author for Correspondence: chandupatil69@gmail.com

rural community and primary healthcare settings to ensure ecological validity and real-world applicability. Ethical approval was obtained prior to commencement, and the study was conducted in accordance with the Declaration of Helsinki.

2.2 Participants

A total of 98 post-CABG patients aged 40–70 years were recruited from the cardiothoracic surgery ward during their postoperative inpatient stay. Participants were screened for eligibility by a cardiologist and physiotherapist and included only if medically stable and cleared for rehabilitation.

Inclusion criteria:

- Individuals who had undergone CABG
- Age between 40 and 70 years
- Male or female participants
- Medically stable and cleared for physiotherapy by the treating physician
- Baseline assessment conducted on day 3 post-CABG (early postoperative phase)
- Residents of rural areas
- Willing to participate and provide written informed consent

Exclusion criteria:

- Postoperative complications including unstable angina, uncontrolled arrhythmias, or haemodynamic instability
- Severe left ventricular dysfunction contraindicating exercise participation
- Significant neurological disorders affecting balance or mobility
- Severe musculoskeletal conditions limiting functional movement or ambulation
- Any medical condition restricting safe participation in exercise-based rehabilitation
- Unwillingness to participate

2.3 Recruitment and Randomisation

Recruitment involved four steps: (1) medical screening for stability and eligibility by the treating team; (2) physiotherapy screening to assess readiness for mobilisation; (3) baseline assessment on postoperative day 3; and (4) written informed consent after explanation of study objectives, procedures, benefits, and risks.

Participants were randomly allocated (1:1) to intervention or control groups using a computer-generated random sequence. Allocation concealment was ensured using sealed opaque envelopes. Outcome assessors were blinded to group allocation. Blinding of participants and treating physiotherapists was not feasible due to the nature of the exercise intervention; this is acknowledged as a limitation.

2.4 Intervention Protocol

Participants in the intervention group received a structured multicomponent exercise programme initiated on postoperative day 3 and continued until day 15 (13 sessions). Table 1 summarises the components of each arm.

Table 1. Structured Multicomponent Exercise Programme vs. Conventional Rehabilitation

Component	Intervention Group	Control Group
Aerobic Training	Walking-based (20–30 min/session, 5 sessions/week, moderate intensity: Borg RPE 11–13)	Light activity / general mobility
Resistance Training	Major muscle groups; 2–3 sets × 10–15 reps using elastic bands/bodyweight	Not included
Flexibility Exercises	Static stretching of major muscle groups	Minimal / not structured
Balance Training	Tandem stance, single-leg stance, functional reach tasks	Not included
Breathing Exercises	Included in warm-up and cool-down phases	Primary intervention component
Progression	Gradual increase in intensity/duration based on patient tolerance and clinical response	No structured progression
Supervision	Structured, monitored programme	General advice only

2.5 Outcome Measures

Three primary outcomes were assessed: systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate recovery (HRR). Table 2 details the measurement methods and clinical interpretation for each outcome.

Table 2. Outcome Measures and Assessment Protocol

Outcome	Method	Procedure	Clinical Interpretation
SBP	Calibrated sphygmomanometer	After 10-min seated rest; mean of two readings (mmHg)	Indicator of cardiovascular load; reduction reflects improved vascular function
DBP	Calibrated sphygmomanometer	After 10-min seated rest; mean of two readings (mmHg)	Reflects peripheral vascular resistance; reduction indicates improved haemodynamic control

HRR	Standardised walking test	HRR = Peak HR − HR at 1 min post-exercise	Higher HRR indicates improved parasympathetic reactivation

Assessments were conducted at two time points: baseline on postoperative day 3 and post-intervention on day 15.

2.6 Statistical Analysis
Data were analysed using IBM SPSS Statistics, Version 26.0. Normality was assessed using the Shapiro–Wilk test. Within-group changes were evaluated with paired t-tests; between-group differences were assessed with independent t-tests and ANCOVA to control for baseline values. Effect sizes were calculated using Cohen's d. Categorical distributions (BP categories) were compared with chi-square tests. Statistical significance was set at $p < 0.05$.

3. Results

3.1 Systolic Blood Pressure

Table 3. Distribution of Systolic Blood Pressure by Category

Category	Day 3 – Control	Day 3 – Intervention	Day 15 – Control	Day 15 – Intervention
Below normal	0	1	2	3
Normal	6	3	6	7
Above normal	44	46	42	40
Between-group p-value	—	—	p = 0.489	

At baseline (postoperative day 3), the distribution of SBP categories was comparable between groups, with the majority of participants in the above-normal category. After the 13-day intervention, both groups demonstrated a reduction in the proportion of above-normal SBP. The intervention group showed a numerically greater shift toward the normal and below-normal categories; however, the between-group difference did not reach statistical significance (p = 0.489). These trends should be interpreted cautiously given the lack of statistical significance. Mean ± SD values for SBP at both time points are recommended for inclusion in future reporting to enable meta-analytic pooling.

3.2 Diastolic Blood Pressure

Table 4. Distribution of Diastolic Blood Pressure by Category

Category	Day 3 – Control	Day 3 – Intervention	Day 15 – Control	Day 15 – Intervention
Below normal	10	5	11	14
Normal	18	29	20	22
Above normal	22	16	19	14
Between-group p-value	—	—	p = 0.154	

At baseline, both groups showed a mixed distribution of DBP categories. After the intervention period, both groups demonstrated improvements reflected by a reduction in the above-normal category. The intervention group showed a numerically greater shift toward the normal range; however, the between-group difference was not statistically significant (p = 0.154). These findings suggest a trend toward improved DBP regulation with structured exercise training, which may become statistically significant with a larger sample or longer intervention.

3.3 Heart Rate Recovery

Table 5. Comparison of Heart Rate Recovery (HRR)

Variable	Group	Day 3 Mean ± SD	Day 15 Mean ± SD	Mean Difference	p-value	Cohen's d
HRR (bpm)	Intervention	12 ± 3	20 ± 4	+8	< 0.001	0.90
HRR (bpm)	Control	13 ± 3	14 ± 3	+1	> 0.05	—

HRR improved significantly in the intervention group, increasing from 12 ± 3 bpm at baseline to 20 ± 4 bpm post-intervention (mean increase +8 bpm; $p < 0.001$; Cohen's d = 0.90, indicating a large effect). In contrast, the control group showed only minimal improvement (+1 bpm; $p > 0.05$). The between-group comparison was statistically significant, with a large effect size, indicating that structured exercise training produced a strong positive impact on autonomic recovery in post-CABG individuals.

4. Discussion

This study evaluated the effect of early structured multicomponent exercise training on blood pressure regulation and autonomic recovery in post-CABG individuals. The principal finding is a significant, large-effect improvement in HRR in the intervention group, supporting enhanced autonomic recovery. Blood pressure trends also favoured the intervention group, though these did not reach statistical significance over the 13-day programme.

4.1 Blood Pressure Findings

While between-group differences in SBP and DBP were not statistically significant, the observed trends are consistent with previous meta-analyses demonstrating that exercise-based cardiac rehabilitation can reduce blood pressure in cardiac populations [5, 11, 12]. It is plausible that a 13-day programme is insufficient to produce statistically detectable group differences in blood pressure — longer interventions (8–12 weeks) in the literature have yielded reductions of approximately 10 mmHg in SBP, which are associated with substantial reductions in cardiovascular morbidity and mortality [13]. The observed categorical shifts in this study may reflect early mechanistic changes — including enhanced endothelial function, increased nitric oxide bioavailability, reduced arterial stiffness, and improved autonomic balance [22] — that would manifest as significant blood pressure differences with continued training.

4.2 Heart Rate Recovery and Autonomic Function

The marked improvement in HRR in the intervention group (mean +8 bpm; $p < 0.001$; $d = 0.90$) is the most significant finding of this study. HRR is a well-established predictor of cardiovascular mortality, with impaired HRR indicating reduced parasympathetic reactivation [2, 14]. The improvement observed here suggests enhanced vagal tone and reduced sympathetic dominance, reflecting meaningful autonomic recovery. These findings are consistent with prior studies demonstrating that exercise training modulates the autonomic nervous system and improves vagal tone [15,16], and with cardiac rehabilitation studies reporting similar HRR improvements following structured exercise [17].

4.3 Early Rehabilitation Advantage

A key strength of this study is the early initiation of exercise from postoperative day 3. Early mobilisation has been shown to improve circulation, prevent postoperative complications, and accelerate functional recovery [7, 18]. The feasibility of achieving a large HRR effect within 13 days supports the clinical rationale for initiating rehabilitation in the early inpatient phase rather than deferring to outpatient settings.

4.4 Comparison with Conventional Rehabilitation

The substantially greater HRR improvement in the intervention group compared to the control group (+8 vs +1 bpm) highlights the importance of structured, progressive, multicomponent exercise programmes over standard care alone. These findings align with evidence that multicomponent programmes are superior to standard care for improving cardiovascular outcomes [10, 19].

4.5 Rural and Clinical Implications

This study is particularly relevant for rural populations, where access to structured cardiac rehabilitation is limited [8, 9]. The programme in this study — using elastic bands, bodyweight exercises, and supervised walking — requires minimal equipment and is deliverable in primary care or community settings. This supports the feasibility of implementing low-cost, structured exercise rehabilitation in resource-limited environments [21, 22].

4.6 Strengths and Limitations

Strengths of this study include its randomised controlled design, allocation concealment, blinded outcome assessment, early intervention initiation (day 3 post-CABG), rural community setting, and inclusion of HRR as an advanced marker of autonomic function. Limitations include the short 13-day intervention period, which may be insufficient to detect statistically significant blood pressure changes; the absence of long-term follow-up; single-centre recruitment limiting generalisability; and the inability to blind participants and treating physiotherapists, which is inherent to exercise trials. Future studies should include longer follow-up periods, continuous ambulatory blood pressure monitoring, and heart rate variability assessment to provide a more comprehensive evaluation of autonomic outcomes.

5. Conclusion

Early structured multicomponent exercise training initiated on postoperative day 3 significantly improves heart rate recovery — a validated marker of autonomic function — in post-CABG individuals, with a large effect size ($d = 0.90$). Favourable but non-significant trends were observed for blood pressure regulation. These findings support the integration of early structured exercise into inpatient cardiac rehabilitation programmes, particularly in rural and resource-limited settings. Longer intervention studies are warranted to confirm blood pressure benefits and establish optimal programme parameters.

References

1. Anderson L, Oldridge N, Thompson DR, Zwisler AD, Rees K, Martin N, Taylor RS. Exercise-Based Cardiac Rehabilitation for Coronary Heart Disease: Cochrane Systematic Review and Meta-Analysis. J Am Coll Cardiol. 2016 Jan 5;67(1):1-12. doi: 10.1016/j.jacc.2015.10.044. PMID: 26764059.
2. Cole CR, Blackstone EH, Pashkow FJ, Snader CE, Lauer MS. Heart-rate recovery immediately after exercise as a predictor of mortality. N Engl J Med. 1999 Oct 28;341(18):1351-7. doi: 10.1056/NEJM199910283411804. PMID: 10536127.
3. Nishime EO, Cole CR, Blackstone EH, Pashkow FJ, Lauer MS. Heart rate recovery and treadmill

exercise score as predictors of mortality in patients referred for exercise ECG. JAMA. 2000 Sep 20;284(11):1392-8. doi: 10.1001/jama.284.11.1392. PMID: 10989401.

4. Mohr FW, Morice MC, Kappetein AP, Feldman TE, Ståhle E, Colombo A, Mack MJ, Holmes DR Jr, Morel MA, Van Dyck N, Houle VM, Dawkins KD, Serruys PW. Coronary artery bypass graft surgery versus percutaneous coronary intervention in patients with three-vessel disease and left main coronary disease: 5-year follow-up of the randomised, clinical SYNTAX trial. Lancet. 2013 Feb 23;381(9867):629-38. doi: 10.1016/S0140-6736(13)60141-5. PMID: 23439102.
5. Taylor RS, Brown A, Ebrahim S, Jolliffe J, Noorani H, Rees K, Skidmore B, Stone JA, Thompson DR, Oldridge N. Exercise-based rehabilitation for patients with coronary heart disease: systematic review and meta-analysis of randomized controlled trials. Am J Med. 2004 May 15;116(10):682-92. doi: 10.1016/j.amjmed.2004.01.009. PMID: 15121495.
6. Piepoli MF, Corrà U, Adamopoulos S, Benzer W, Bjarnason-Wehrens B, Cupples M, Dendale P, Doherty P, Gaita D, Höfer S, McGee H, Mendes M, Niebauer J, Pogosova N, Garcia-Porrero E, Rauch B, Schmid JP, Giannuzzi P. Secondary prevention in the clinical management of patients with cardiovascular diseases. Core components, standards and outcome measures for referral and delivery: a policy statement from the cardiac rehabilitation section of the European Association for Cardiovascular Prevention & Rehabilitation. Endorsed by the Committee for Practice Guidelines of the European Society of Cardiology. Eur J Prev Cardiol. 2014 Jun;21(6):664-81. doi: 10.1177/2047487312449597. Epub 2012 Jun 20. PMID: 22718797.
7. Balady GJ, Ades PA, Bittner VA, Franklin BA, Gordon NF, Thomas RJ, Tomaselli GF, Yancy CW; American Heart Association Science Advisory and Coordinating Committee. Referral, enrollment, and delivery of cardiac rehabilitation/secondary prevention programs at clinical centers and beyond: a presidential advisory from the American Heart Association. Circulation. 2011 Dec 20;124(25):2951-60. doi: 10.1161/CIR.0b013e31823b21e2. Epub 2011 Nov 14. PMID: 22082676.
8. Dalal HM, Doherty P, Taylor RS. Cardiac rehabilitation. BMJ. 2015 Sep 29;351:h5000. doi: 10.1136/bmj.h5000. PMID: 26419744; PMCID: PMC4586722.
9. Resurrección DM, Moreno-Peral P, Gómez-Herranz M, Rubio-Valera M, Pastor L, Caldas de Almeida JM, Motrico E. Factors associated with non-participation in and dropout from cardiac rehabilitation programmes: a systematic review of prospective cohort studies. Eur J Cardiovasc Nurs. 2019 Jan;18(1):38-47. doi: 10.1177/1474515118783157. Epub 2018 Jun 18. PMID: 29909641.
10. Weston KS, Wisløff U, Coombes JS. High-intensity interval training in patients with lifestyle-induced cardiometabolic disease: a systematic review and meta-analysis. Br J Sports Med. 2014 Aug;48(16):1227-34. doi: 10.1136/bjsports-2013-092576. Epub 2013 Oct 21. PMID: 24144531.
11. Cornelissen, Veronique & Smart, Neil. (2013). Exercise Training for Blood Pressure: A Systematic Review and Meta-analysis. Journal of the American Heart Association. 2. e004473. 10.1161/JAHA.112.004473.
12. Whelton SP, Chin A, Xin X, He J. Effect of aerobic exercise on blood pressure: a meta-analysis of randomized, controlled trials. Ann Intern Med. 2002 Apr 2;136(7):493-503. doi: 10.7326/0003-4819-136-7-200204020-00006. PMID: 11926784.
13. Lewington S, Clarke R, Qizilbash N, Peto R, Collins R; Prospective Studies Collaboration. Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. Lancet. 2002 Dec 14;360(9349):1903-13. doi: 10.1016/s0140-6736(02)11911-8. Erratum in: Lancet. 2003 Mar 22;361(9362):1060. PMID: 12493255.
14. Shetler K, Marcus R, Froelicher VF, Vora S, Kalisetti D, Prakash M, Do D, Myers J. Heart rate recovery: validation and methodologic issues. J Am Coll Cardiol. 2001 Dec;38(7):1980-7. doi: 10.1016/s0735-1097(01)01652-7. PMID: 11738304.
15. Carter JB, Banister EW, Blaber AP. Effect of endurance exercise on autonomic control of heart rate. Sports Med. 2003;33(1):33-46. doi: 10.2165/00007256-200333010-00003. PMID: 12477376.
16. Routledge FS, Campbell TS, McFetridge-Durdle JA, Bacon SL. Improvements in heart rate variability with exercise therapy. Can J Cardiol. 2010 Jun-Jul;26(6):303-12. doi: 10.1016/s0828-282x(10)70395-0. PMID: 20548976; PMCID: PMC2903986.
17. Maddison R, Whittaker R, Stewart R, Kerr A, Jiang Y, Kira G, Carter KH, Pfaeffli L. HEART: heart exercise and remote technologies: a randomized controlled trial study protocol. BMC Cardiovasc Disord. 2011 May 31;11:26. doi: 10.1186/1471-2261-11-26. PMID: 21624142; PMCID: PMC3118189.
18. Herdy AH, López-Jiménez F, Terzic CP, Milani M, Stein R, Carvalho T, Serra S, Araujo CG, Zeballos PC, Anchique CV, Burdiat G, González K, González G, Fernández R, Santibáñez C, Rodríguez-Escudero JP, Ilarraza-Lomelí H. South American guidelines for cardiovascular disease prevention and rehabilitation. Arq Bras Cardiol. 2014 Aug;103(2 Suppl 1):1-31. English, Portuguese. doi: 10.5935/abc.2014s003. PMID: 25387466.

19. Ades PA, Keteyian SJ, Wright JS, Hamm LF, Lui K, Newlin K, Shepard DS, Thomas RJ. Increasing Cardiac Rehabilitation Participation From 20% to 70%: A Road Map From the Million Hearts Cardiac Rehabilitation Collaborative. Mayo Clin Proc. 2017 Feb;92(2):234-242. doi: 10.1016/j.mayocp.2016.10.014. Epub 2016 Nov 15. PMID: 27855953; PMCID: PMC5292280.
20. Lavie CJ, Arena R, Franklin BA. Cardiac Rehabilitation and Healthy Life-Style Interventions: Rectifying Program Deficiencies to Improve Patient Outcomes. J Am Coll Cardiol. 2016 Jan 5;67(1):13-5. doi: 10.1016/j.jacc.2015.09.103. PMID: 26764060.
21. Thomas RJ, Beatty AL, Beckie TM, Brewer LC, Brown TM, Forman DE, Franklin BA, Keteyian SJ, Kitzman DW, Regensteiner JG, Sanderson BK, Whooley MA. Home-Based Cardiac Rehabilitation: A Scientific Statement From the American Association of Cardiovascular and Pulmonary Rehabilitation, the American Heart Association, and the American College of Cardiology. J Am Coll Cardiol. 2019 Jul 9;74(1):133-153. doi: 10.1016/j.jacc.2019.03.008. Epub 2019 May 13. PMID: 31097258; PMCID: PMC7341112.
22. Green DJ, Maiorana A, O'Driscoll G, Taylor R. Effect of exercise training on endothelium-derived nitric oxide function in humans. J Physiol. 2004 Nov 15;561(Pt 1):1-25. doi: 10.1113/jphysiol.2004.068197. Epub 2004 Sep 16. PMID: 15375191; PMCID: PMC1665322.