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# Deep breathing versus rhythmic breathing exercises for post-sternotomy pain and inspiratory function in phase-I cardiac rehabilitation after CABG: A randomized controlled trial

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**Abstract**
**Background:** Coronary artery disease (CAD) remains a leading cause of global morbidity and mortality, with a disproportionately high burden in South Asia driven by traditional cardiometabolic risk factors alongside elevated lipoprotein(a) and apolipoprotein B levels. Coronary artery bypass grafting (CABG) effectively restores myocardial perfusion, yet acute post-sternotomy pain frequently triggers sympathetic overactivity, splinted shallow breathing, and postoperative pulmonary complications. Simple non-pharmacological adjuncts such as deep breathing exercise (DBE) and rhythmic breathing exercise (RBE) may alleviate surgical pain and accelerate respiratory recovery, but direct comparative data during early inpatient rehabilitation remain limited.
**Objective:** To evaluate and compare the effectiveness of DBE versus RBE as adjuncts to standard Phase-I cardiac physiotherapy in reducing post-sternotomy pain and improving inspiratory effort following off-pump CABG.
**Methods:** In this two-group, pre-test/post-test, non-randomised comparative study, 64 patients undergoing off-pump CABG were screened at KIMS General Hospital, Amalapuram. Four were excluded before allocation (two ineligible, two discontinued early). The remaining 60 participants, aged 30–80 years and recruited by convenience sampling, were assigned equally to Group A (DBE + conventional physiotherapy, n = 30) or Group B (RBE + conventional physiotherapy, n = 30). Both groups received three supervised sessions daily for 7 consecutive days alongside the same baseline analgesia and standard Phase-I physiotherapy. Pain intensity was measured with a 10-cm Visual Analogue Scale (VAS) and inspiratory effort with a volume-oriented incentive spirometer (Coach 2, mL) on postoperative Day 1 (baseline) and Day 7. Paired and independent-samples t-tests were applied ($\alpha = 0.05$).
**Results:** All 60 participants completed the 7-day protocol. Baseline VAS pain (8.50 ± 0.51 cm) and inspiratory effort (1083.33 ± 309.47 mL) were identical in both groups. By Day 7, both groups demonstrated statistically significant within-group improvements ($p < 0.001$). Mean VAS pain decreased by 5.23 cm (61.6%) in Group A and by 6.93 cm (81.6%) in Group B, yielding significantly lower post-test pain in the RBE group (1.57 ± 0.63 cm vs. 3.27 ± 0.45 cm; $t = 12.08$, $p < 0.001$). Inspiratory effort increased by 2283.33 mL (210.8%) in Group A and by 2766.67 mL (255.4%) in Group B, with significantly greater Day 7 volume in the RBE group (3850.00 ± 645.27 mL vs. 3366.67 ± 507.42 mL; $t = 3.23$, $p = 0.002$).
**Conclusion:** Both DBE and RBE significantly reduced post-sternotomy pain and improved inspiratory volume when added to standard Phase-I physiotherapy after CABG, with RBE showing greater analgesic and inspiratory gains. Given the non-randomised allocation and short 7-day inpatient window, assessor-blinded randomised controlled trials with extended follow-up are recommended to confirm these findings.

**Keywords:** Coronary artery bypass grafting, deep breathing exercise, rhythmic breathing exercise, post-sternotomy pain, inspiratory effort, phase-I cardiac rehabilitation

## Introduction

Cardiovascular diseases (CVDs) represent the single largest cause of mortality globally, accounting for roughly 16% of all deaths worldwide [1]. Global Burden of Disease analyses from 1990 to 2023 demonstrate a substantial rise in cardiovascular burden, with disability-adjusted life years (DALYs) increasing 1.4-fold from approximately 320 million to 437 million and annual global CVD deaths rising from 13.1 million to 19.2 million, largely propelled by population ageing and escalating cardiometabolic risk factors such as hypertension and diabetes mellitus [2]. Within this spectrum, coronary artery disease (CAD) affects roughly 4–5% of adults globally, with an estimated age-standardised prevalence of 3,605 per 100,000 population [3, 4]. In India, epidemiological surveys highlight a growing burden across both urban (2.5% to 12.6%) and rural (1.4% to 4.6%) communities, reflecting rapid urbanisation and lifestyle shifts [5].

Individuals of South Asian ancestry face an elevated risk of premature and severe CAD mortality. This heightened susceptibility stems from two converging mechanisms: a high prevalence of conventional risk factors (hypertension, diabetes, dyslipidaemia, and tobacco use) and distinctive atherogenic lipid biomarkers such as elevated lipoprotein(a), apolipoprotein B-100, and C-reactive protein [6]. For patients with complex multivessel CAD refractory to optimal medical therapy, coronary artery bypass grafting (CABG) remains the gold-standard surgical revascularisation procedure, restoring myocardial perfusion and improving long-term survival with over one million procedures performed annually worldwide [7, 8].

Despite its life-saving efficacy, CABG is an invasive surgical trauma associated with acute postoperative pain and pulmonary morbidity, including atelectasis, restrictive ventilatory dysfunction, and hypoxaemia [9]. Acute postoperative pain arises from median sternotomy, chest wall retraction, internal thoracic artery or saphenous vein harvesting, and intercostal chest drain placement [10]. During the first 24 to 72 hours after surgery, severe sternotomy pain impairs effective coughing and forces patients into a rapid, shallow breathing pattern that promotes basal alveolar collapse and venous stasis [11]. Pain-induced nociceptive stimulation also triggers sympathetic nervous system activation, elevating circulating catecholamines, heart rate, blood pressure, and myocardial oxygen demand, which can precipitate perioperative myocardial ischaemia [12]. Furthermore, inadequately controlled acute sternotomy pain increases the risk of chronic post-sternotomy pain syndrome lasting 6 to 12 months and impairing health-related quality of life [13, 15].

Although systemic analgesics such as opioids and non-steroidal anti-inflammatory drugs (NSAIDs) form the cornerstone of postoperative pain control, high opioid doses carry risks of respiratory depression, sedation, nausea, and delayed mobilisation [16]. Consequently, multimodal cardiac rehabilitation incorporates non-pharmacological strategies including relaxation, distraction, music, cryotherapy, incentive spirometry, and structured breathing exercises to enhance patient comfort and reduce analgesic reliance [17, 18]. Deep breathing exercise (DBE) is a foundational respiratory physiotherapy technique performed slowly and smoothly to promote diaphragmatic excursion, alveolar recruitment, and somatic relaxation [19]. Rhythmic breathing exercise (RBE), by contrast, combines paced, count-guided inhalation, breath-holding, and exhalation with focused attentional awareness. Through sensory distraction and respiratory sinus entrainment, RBE modulates brainstem reticular pain gating, increases vagal parasympathetic tone, and dampens sympathetic arousal and anxiety [20, 23].

Because sternotomy pain is most intense during deep inspiration and coughing [24, 25], identifying which breathing strategy best relieves pain while restoring lung volume during early inpatient recovery is clinically important. Therefore, this study aimed to evaluate and compare the effectiveness of DBE and RBE as adjuncts to standard Phase-I cardiac physiotherapy in reducing post-sternotomy pain and improving inspiratory effort in patients following CABG. The null hypothesis stated that there would be no significant difference between DBE and RBE in reducing pain or improving inspiratory effort, whereas the alternative hypothesis posited a statistically significant difference between the two interventions.

## Methods

### 1. Study Design, Setting, and Ethical Approval

This study employed a non-randomised, two-group, pre-test/post-test comparative design conducted in the inpatient cardiothoracic surgical wards of KIMS General Hospital, Amalapuram, Andhra Pradesh, India. Ethical clearance was obtained from the Institutional Ethics Committee of KIMS College of Physiotherapy, Amalapuram. Written informed consent was obtained from every participant after providing a detailed subject information sheet and explaining the study procedures, ensuring full protection of participant rights.

### 2. Participants and Group Allocation

A total of 64 postoperative CABG patients were recruited via convenience sampling and screened for eligibility. Four were excluded before allocation: two did not meet the inclusion criteria and two discontinued participation early. The remaining 60 participants were assigned equally to two parallel intervention arms: Group A (DBE + conventional physiotherapy, n = 30) and Group B (RBE + conventional physiotherapy, n = 30). Because participants were recruited by convenience sampling without formal, concealed random sequence generation, the study is classified as a non-randomised comparative study. Participant flow is shown in Figure 1.

**Inclusion Criteria:** Patients were eligible if they met all of the following criteria: (1) male or female aged 30 to 80 years; (2) conscious, oriented, and able to follow verbal instructions; (3) undergoing elective, primary off-pump CABG (without cardiopulmonary bypass); (4) haemodynamically stable following extubation on postoperative Day 1; (5) free of clinically significant postoperative arrhythmias; and (6) receiving the standardised institutional baseline postoperative analgesic regimen to ensure pharmacological uniformity across groups.

**Exclusion Criteria:** Patients were excluded if they had: (1) prolonged mechanical ventilation (>24 hours); (2) ongoing dependence on inotropic support for haemodynamic stability after extubation; (3) pre-existing chronic respiratory disease; (4) prior cardiac surgery; (5) renal dysfunction requiring dialysis; (6) arterial partial pressure of oxygen (PaO2) < 60 mmHg without supplemental nasal oxygen; or (7) a documented history of severe psychiatric or cognitive illness.

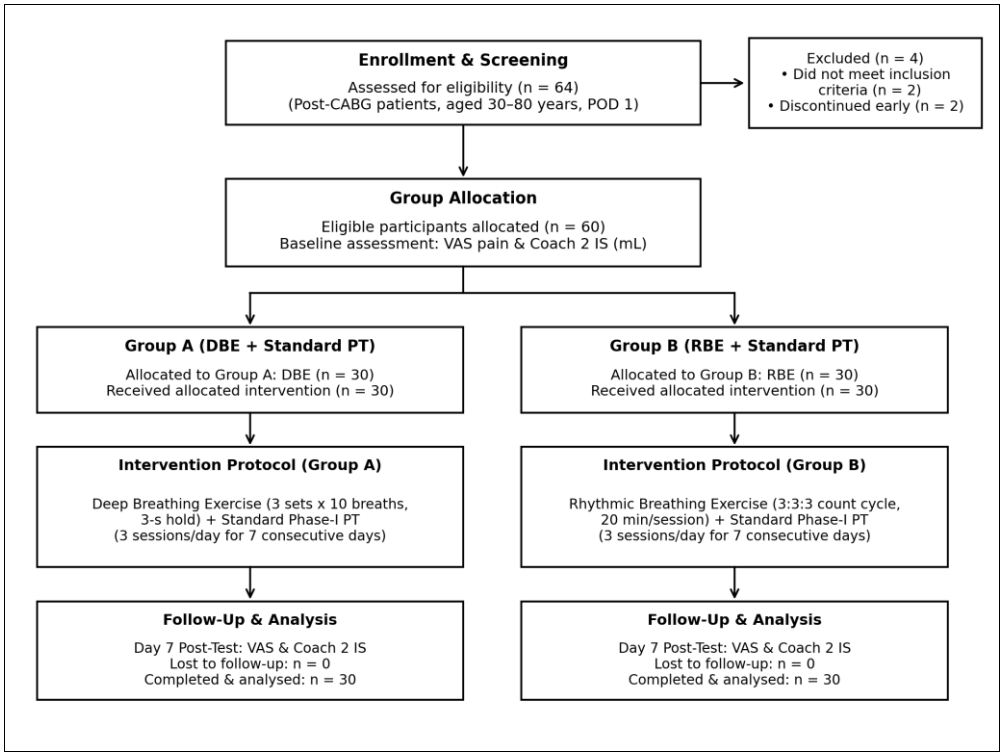



**Fig 1:** Participant screening, group allocation, intervention protocol, and follow-up flow diagram. CABG, coronary artery bypass grafting; POD 1, postoperative Day 1; VAS, Visual Analogue Scale; IS, incentive spirometer; DBE, deep breathing exercise; RBE, rhythmic breathing exercise; PT, physiotherapy.

## 3. Outcome Measures

All assessments were conducted at baseline (postoperative Day 1, after extubation and haemodynamic stabilisation) and upon completion of the 7-day inpatient protocol (postoperative Day 7) using standard clinical equipment (adjustable hospital bed, armed chair, pulse oximeter, sternal support brace/chest binder, and walking frame).

1. **Visual Analogue Scale (VAS):** Post-sternotomy pain intensity was quantified using a 10-cm horizontal Visual Analogue Scale anchored at 0 cm ('no pain') and 10 cm ('most severe pain imaginable'). Participants marked their perceived pain level on the line, and the distance from the left anchor was recorded in centimetres. The VAS is a valid, reliable, and responsive instrument for acute postoperative pain assessment [26, 27].

2. **Volume-Oriented Incentive Spirometer (Coach 2 Device):** Inspiratory volume (effort) was measured in millilitres (mL) using a volume-oriented incentive spirometer (Coach 2 device; Smiths Medical). Participants performed slow, maximal inspirations from functional residual capacity while seated upright, and the highest of three consecutive efforts was recorded. Volume-oriented incentive spirometry imposes low work of breathing and reliably reflects diaphragmatic excursion and inspiratory lung expansion following cardiothoracic surgery [28].

## 4. Intervention Protocols

Both groups received standard Phase-I inpatient cardiac physiotherapy alongside their assigned breathing intervention for 7 consecutive days. Standard physiotherapy comprised volume-oriented incentive spirometry, splinted coughing and huffing for airway clearance, active range-of-motion exercises for the upper and lower extremities, gentle thoracic mobility exercises, education on sternal precautions, and staged early mobilisation progressing from bedside sitting and standing to supported ward ambulation and stair climbing [28, 29].

**Group A – Deep Breathing Exercise + Conventional Physiotherapy (n = 30):** Participants were positioned in a supported half-lying (semi-recumbent) posture with shoulders relaxed and the abdominal wall soft. Both hands were placed gently below the anterior costal margin over the rectus abdominis to provide tactile feedback. Participants inhaled slowly and deeply through the nose from functional residual capacity toward total lung capacity, maintained a 3-second end-inspiratory hold, and exhaled slowly through pursed lips while minimising upper-chest accessory motion. Each supervised session consisted of 3 sets of 10 deep breaths (30 breaths total) with 30–60 seconds of rest between sets, administered 3 times daily for 7 consecutive days [30].

**Group B – Rhythmic Breathing Exercise + Conventional Physiotherapy (n = 30):** Participants rested in a comfortable supported position with eyes closed to reduce external visual distraction. Each breathing cycle followed a structured 1-to-3 mental count: slow nasal inhalation during a count of 1 to 3, a controlled end-inspiratory breath holds for a count of 1 to 3, and slow oral exhalation for a count of 1 to 3, while maintaining continuous mental focus on the sensation of airflow. Each 20-minute session comprised 1-

minute rhythmic breathing cycles separated by brief rest intervals, delivered 3 times daily for 7 consecutive days [31, 32].

### 5. Statistical Analysis

Data were compiled in Microsoft Excel 2007 and analysed using IBM SPSS Statistics version 21.0 (IBM Corp., Armonk, NY, USA). Continuous variables are presented as mean ± standard deviation (SD). Within-group changes between Day 1 (pre-test) and Day 7 (post-test) were evaluated using paired-samples t-tests, while between-group differences at Day 7 were assessed using independent-samples t-tests. Statistical significance was set at a two-sided $p < 0.05$. Between-group mean differences are reported with 95% confidence intervals (CI).

## Results

All 60 participants (30 in Group A and 30 in Group B) completed the 7-day inpatient rehabilitation programme without adverse events or dropouts (Figure 1). Baseline VAS pain (8.50 ± 0.51 cm) and inspiratory effort (1083.33 ± 309.47 mL) were identical in both groups before the intervention.

### 1. Post-Sternotomy Pain Intensity (VAS)

Both breathing interventions produced statistically significant within-group reductions in post-sternotomy pain from Day 1 to Day 7 (Table 1 and Figure 2A). In Group A (DBE), mean VAS pain decreased by 5.23 cm (61.6%), from 8.50 ± 0.51 cm to 3.27 ± 0.45 cm ($p < 0.001$). In Group B (RBE), it decreased by 6.93 cm (81.6%), from 8.50 ± 0.51 cm to 1.57 ± 0.63 cm ($p < 0.001$). At Day 7, residual pain was significantly lower in the RBE group than in the DBE group (mean difference 1.70 cm, 95% CI 1.42 to 1.98; $t = 12.08$, $df = 58$, $p < 0.001$).

### 2. Inspiratory Effort (Coach 2 Incentive Spirometry)

Both groups achieved substantial within-group gains in inspiratory volume over the 7-day period (Table 2 and Figure 2B). In Group A (DBE), mean inspiratory effort rose by 2283.33 mL (210.8%), from 1083.33 ± 309.47 mL to 3366.67 ± 507.42 mL ($p < 0.001$). In Group B (RBE), it rose by 2766.67 mL (255.4%), from 1083.33 ± 309.47 mL to 3850.00 ± 645.27 mL ($p < 0.001$). At Day 7, the RBE group achieved a significantly greater inspiratory volume than the DBE group (mean difference 483.33 mL, 95% CI 183.33 to 783.33; $t = 3.23$, $df = 58$, $p = 0.002$).

**Table 1:** Pain intensity (VAS, cm) at postoperative Day 1 and Day 7.

| Group | Day 1 | Day 7 | Change (%) | p (within group) |
|---|---|---|---|---|
| DBE (n = 30) | 8.50 ± 0.51 | 3.27 ± 0.45 | −5.23 (−61.6%) | < 0.001 |
| RBE (n = 30) | 8.50 ± 0.51 | 1.57 ± 0.63 | −6.93 (−81.6%) | < 0.001 |
| Between-group difference at Day 7 (RBE − DBE): −1.70 cm (95% CI −1.98 to −1.42); t = 12.08; p < 0.001 | | | | |

Values are mean ± SD. VAS, Visual Analogue Scale (0–10 cm); DBE, deep breathing exercise; RBE, rhythmic breathing exercise. Within-group p-values: paired t-test. Between-group comparison at Day 7: independent-samples t-test (df = 58).

**Table 2:** Inspiratory effort (Coach 2 incentive spirometer, mL) at postoperative Day 1 and Day 7.

| Group | Day 1 | Day 7 | Change (%) | p (within group) |
|---|---|---|---|---|
| DBE (n = 30) | 1083.33 ± 309.47 | 3366.67 ± 507.42 | +2283.33 (+210.8%) | < 0.001 |
| RBE (n = 30) | 1083.33 ± 309.47 | 3850.00 ± 645.27 | +2766.67 (+255.4%) | < 0.001 |
| Between-group difference at Day 7 (RBE − DBE): +483.33 mL (95% CI 183.33 to 783.33); t = 3.23; p = 0.002 | | | | |

Values are mean ± SD. DBE, deep breathing exercise; RBE, rhythmic breathing exercise. Within-group p-values: paired t-test. Between-group comparison at Day 7: independent-samples t-test (df = 58).

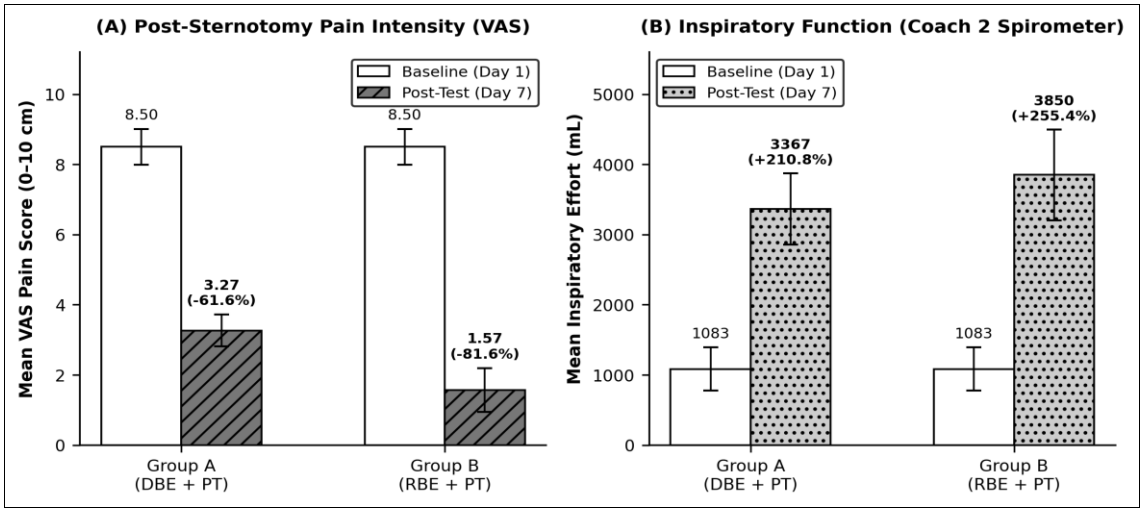



**Fig 2:** Pre-test (Day 1) and post-test (Day 7) outcomes across intervention groups. (A) Mean Visual Analogue Scale (VAS) pain intensity scores (cm) with ±1 SD error bars and percentage reductions. (B) Mean inspiratory effort (mL) measured using the Coach 2 volume-oriented incentive spirometer with ±1 SD error bars and percentage increases.

## Discussion

The present study evaluated and compared the short-term clinical effectiveness of Deep Breathing Exercise (DBE) and Rhythmic Breathing Exercise (RBE) as adjuncts to conventional Phase-I cardiac physiotherapy in 60 patients recovering from off-pump CABG. While both interventions

significantly reduced post-sternotomy pain and increased inspiratory volume over the 7-day hospitalisation period, patients practising RBE experienced significantly greater pain relief (81.6% vs. 61.6% reduction) and achieved higher inspiratory spirometry volumes (3850.00 mL vs. 3366.67 mL) than those performing DBE. Consequently, the null hypothesis was rejected in favour of the alternative hypothesis within this non-randomised sample.

Acute pain following median sternotomy is a primary driver of protective chest-wall splinting, shallow tidal breathing, and impaired mucociliary clearance, predisposing patients to postoperative atelectasis and hypoxaemia [33]. In our cohort, participants in Group A (DBE) achieved a meaningful 5.23-cm reduction in VAS pain scores alongside a 2283.33-mL increase in inspiratory volume. Slow, deep diaphragmatic inhalations stimulate pulmonary stretch receptors, dampen sympathetic outflow, and promote somatic relaxation [34]. Mechanically, sustained maximal inspiration mobilises the costosternal and costovertebral articulations, reduces intercostal muscle guarding around the sternal incision, and promotes collateral alveolar ventilation [33, 35]. However, because conventional DBE relies primarily on biomechanical lung expansion without structured rhythmic pacing or attentional redirection, its analgesic effect may have been comparatively smaller.

Conversely, Group B (RBE) demonstrated superior analgesia and ventilatory performance. Several converging neurophysiological and psychological mechanisms may explain this advantage. First, slow, count-guided breathing cycles (a 3:3:3 count cycle of inhalation, hold, and exhalation) engage pulmonary stretch receptors and baroreceptor reflexes more consistently than unpaced breathing, shifting autonomic balance toward vagal parasympathetic dominance and enhancing heart rate variability and respiratory sinus arrhythmia [36, 37]. Second, voluntary rhythmic breathing propagates hyperpolarising inhibitory signals across cardiorespiratory, limbic, and cortical networks, reducing emotional reactivity, postoperative anxiety, and pain catastrophising [36, 38]. Third, focused mental counting acts as a cognitive distraction that gates nociceptive transmission at the brainstem reticular formation [20, 22, 39]. Finally, metronomic pacing may avoid abrupt intrathoracic pressure spikes that could place shear stress on the healing sternum [40], enabling patients to perform deeper, more comfortable inspirations on the incentive spirometer [41, 43].

Our clinical results corroborate prior randomised trials in cardiothoracic and cardiac populations. Babamohamadi *et al*. [31] and Nasirnejad *et al*. [44] similarly reported that structured rhythmic breathing significantly attenuates sternotomy pain and procedural anxiety in post-CABG patients, while Joshi and Singh [45] and Othman *et al*. [46] demonstrated that structured breathing protocols paired with incentive spirometry accelerate pulmonary recovery after cardiac surgery. Because both groups in our study received identical baseline analgesia and standardised Phase-I mobilisation and airway clearance [28, 29], the additional gains observed in Group B may be attributable to the structured rhythmic pacing and attentional-focus components of RBE, although residual confounding cannot be excluded.

### 1. Limitations and Recommendations for Future Research

Several methodological limitations should be considered when interpreting these findings. First, group assignment relied on convenience sampling without concealed random sequence generation, and outcome assessors were not blinded, introducing potential selection and detection bias. Second, baseline demographic and surgical variables, such as age distribution, sex ratio, body mass index, number of bypass grafts, and daily opioid consumption, were not tabulated, limiting adjustment for confounders. Third, paired t-statistics and participant-level change-score SDs are not reported, and the VAS, an ordinal-type scale, was analysed with parametric tests. Fourth, the single-centre sample (n = 60) and 7-day inpatient observation window preclude conclusions about long-term pulmonary function or chronic post-sternotomy pain. Future multicentre, assessor-blinded randomised controlled trials with larger cohorts, detailed analgesic tracking, and 3- to 12-month follow-up are warranted.

## Conclusion

Both deep breathing exercise and rhythmic breathing exercise significantly reduced post-sternotomy pain and improved inspiratory effort when added to conventional Phase-I physiotherapy after CABG. Rhythmic breathing exercise yielded greater pain relief and higher inspiratory spirometry volumes at postoperative Day 7. Because RBE is simple, non-invasive, low-cost, and easily taught at the bedside, it may be considered a useful adjunct in early post-CABG cardiac rehabilitation, pending confirmation in assessor-blinded randomised trials.

## Declarations

**Author Contributions:** Ganja Preethi Kavya conceptualised the study, recruited participants, delivered the clinical interventions, collected data, and drafted the initial manuscript. Ponnada Ramakrishna supervised the study design, verified statistical analyses, and critically revised the manuscript as corresponding author. Chennupati Ashok Chakravarthi provided institutional support, administrative permissions, and clinical oversight. K. Divya Sundar assisted with methodology refinement and manuscript review.

**Ethical Approval and Consent:** Ethical clearance was obtained from the Institutional Ethics Committee of KIMS College of Physiotherapy, Amalapuram, Andhra Pradesh, India. Written informed consent was obtained from all study participants prior to enrolment.

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**Conflicts of Interest:** The authors declare no conflicts of interest.

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