Comparative Effects of Incentive Spirometer versus Inspiratory Muscle Trainer on Diaphragmatic Excursion Post-Coronary Artery Bypass Graft Surgery

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Abstract

Aims: This study aimed to compare the effectiveness of Incentive Spirometry (IS) and Inspiratory Muscle Training (IMT) on diaphragmatic excursion in patients undergone coronary artery bypass graft (CABG) surgery.

Methods: Fifty-two patients scheduled for elective CABG were randomized into two groups. Group A received conventional physiotherapy with IS, while Group B underwent physiotherapy with IMT. Diaphragmatic excursion was assessed pre- and post-intervention using ultrasound imaging.

Results: Both groups showed significant improvement in diaphragmatic excursion (IS: 3.6 ± 0.5 cm to 4.8 ± 0.9 cm, IMT: 3.7 ± 0.7 cm to 5.05 ± 0.7 cm; $p < 0.001$ within groups). No statistically significant difference was found between the groups post-treatment ($p = 0.31$).

Conclusion: Both IS and IMT significantly improve diaphragmatic excursion following CABG surgery. Either modality can be effectively implemented based on clinical and logistical considerations.

Keywords: Coronary artery bypass graft, incentive spirometry, inspiratory muscle training, diaphragmatic excursion, postoperative rehabilitation

INTRODUCTION

Coronary artery disease (CAD) is a significant public health issue, representing the leading cause of death worldwide (1). The progressive narrowing of coronary arteries due to atherosclerotic plaque buildup leads to myocardial ischemia, angina, and potentially myocardial infarction (2). Coronary artery bypass graft (CABG) surgery is often the intervention of choice in cases of multivessel CAD, particularly when percutaneous coronary interventions are insufficient (3). Despite advances in surgical techniques and perioperative care, CABG remains associated with high morbidity due to postoperative pulmonary complications (PPCs), which include atelectasis, pneumonia, pleural effusions, and diaphragmatic dysfunction (4).

A critical component contributing to these complications is the impairment of respiratory mechanics, particularly the function of the diaphragm, the principal muscle of respiration (5). Diaphragmatic excursion, which reflects the displacement of the diaphragm during breathing, often diminishes after CABG surgery due to factors like phrenic nerve injury, general anesthesia, prolonged immobilization, and pain-induced respiratory inhibition (6). Consequently, strategies to mitigate diaphragmatic dysfunction and improve pulmonary outcomes are essential (7).

Respiratory therapy interventions, particularly the use of Incentive Spirometry (IS) and Inspiratory Muscle Training (IMT), are widely employed to enhance pulmonary function and prevent PPCs (8). IS is a low-cost device designed to encourage deep breathing and lung expansion through visual feedback mechanisms, promoting alveolar inflation and secretion mobilization (9). Conversely, IMT utilizes resistance-based inspiratory exercises to strengthen respiratory muscles, including the diaphragm, potentially offering superior improvements in inspiratory muscle performance (10).

Although both techniques aim to improve respiratory outcomes, their comparative effectiveness, especially in terms of diaphragmatic excursion, remains underexplored (11). Diaphragmatic excursion can be accurately assessed via ultrasonography, a non-invasive, bedside tool that quantifies diaphragmatic motion during respiration and is strongly correlated with respiratory function and lung volume (12).

This study seeks to compare the effects of IS and IMT on diaphragmatic excursion in patients undergone elective CABG surgery. The hypothesis is that while both modalities will enhance diaphragmatic motion postoperatively, IMT, due to its resistance training mechanism, might induce superior improvements in diaphragmatic excursion compared to IS (13).

MATERIALS AND METHODS

This randomized controlled study involved 52 patients scheduled for elective CABG with median sternotomy between April 2022 and April 2023. Patients were recruited from the intensive care unit (ICU) and surgical departments at the National Heart Institute. Inclusion criteria included age 40–65 years, BMI <30 kg/m2, and absence of diabetes or hemodynamic complications such as myocardial infarction or prolonged postoperative ventilation (>24 hours). Exclusion criteria also included renal failure and arrhythmias requiring pacemakers. Seven patients were excluded due to complications, leaving 53 for final analysis.

Participants were randomly assigned into two intervention groups:

Group A (n=26): Received conventional physical therapy and Incentive Spirometry (IS).

Group B (n=26): Received conventional physical therapy and Inspiratory Muscle Training (IMT).

Interventions: Group A patients used a flow oriented IS device with three connected chambers, where patients were instructed to perform 10 repetitions per session for 15 minutes, three times daily. The IS provided real-time visual feedback and encouraged deeper, sustained inhalations.

Group B patients underwent IMT using a threshold-based trainer. The initial training intensity was set at 30% of their Maximal Inspiratory Pressure (MIP), which was progressively increased by 7 cm H2O every two weeks. Each IMT session consisted of six 5-minute sets, performed three times per week, with 5-minute rest intervals between sets. Patients were advised on precautions, including avoiding eating before sessions and using a nasal clip to ensure maximal inspiratory engagement.

Evaluation and Outcome Measure: Diaphragmatic excursion was assessed via ultrasound using a 3.5 MHz probe.

Measurements were taken from end-expiration to total lung capacity with the transducer positioned at a 45-degree angle to optimize visibility of the diaphragm. The right hemidiaphragm motion was selected as the primary outcome variable due to better imaging feasibility and consistent anatomical landmarks.

Statistical Analysis: Descriptive statistics included means and standard deviations for demographic and outcome variables. Within-group comparisons were analyzed using paired t-tests, and between-group comparisons were analyzed using unpaired t-tests. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Baseline demographics revealed no statistically significant differences between groups in age, height, weight, or BMI ($p>0.05$). The mean age was 53.3 ± 6.8 years for the IS group and 52.9 ± 7.9 years for the IMT group. The mean BMI was 28.7 ± 1.53 kg/m2 for the IS group and 28.3 ± 1.5 kg/m2 for the IMT group.

The pre-treatment diaphragmatic excursion was 3.6 ± 0.5 cm in the IS group and 3.7 ± 0.7 cm in the IMT group ($p = 0.64$), indicating homogeneity between groups before intervention. Post-treatment measurements demonstrated significant improvement in both groups. The IS group improved to 4.8 ± 0.9 cm ($p < 0.001$), while the IMT group improved to 5.05 ± 0.7 cm ($p < 0.001$).

However, the between-group comparison of post-treatment values showed no statistically significant difference ($p = 0.31$), suggesting that both interventions were comparably effective in improving diaphragmatic excursion after CABG.

Table 1: comparison between diaphragmatic excursion in(cm) of both groups pre and post ttt

	group	Number	Mean	Standard deviation	P-value	Significance
Pre ttt	IS	26	3.6	0.5	0.64	Non-sig.
	IMT	26	3.7	0.7		
Post ttt	IS	26	4.8	0.9	0.31	Non-sig.
	IMT	26	5.05	0.7		

ttt treatment

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A comparison of pre- and post-treatment outcomes revealed statistically significant improvements in both the Incentive Spirometry (IS) and Inspiratory Muscle Training (IMT) groups. In the IS group, the mean score increased from 3.6 ± 0.5 before treatment to 4.8 ± 0.9 after treatment, with a p-value of 0.0001, indicating a highly significant improvement. Similarly, the IMT group demonstrated a mean increase from 3.7 ± 0.7 pre-treatment to 5.05 ± 0.7 post-treatment, also with a p-value of 0.0001. These results suggest that both interventions were effective in enhancing the measured outcomes, with IMT showing a slightly greater post-treatment mean. The statistical significance underscores the reliability of the observed effects.

Table 2: comparison of means of diaphragmatic excursion in (cm) pre and post treatment on both groups

Groups	measurement	Mean	Standard deviation	P-value	Significance
IS	Pre ttt	3.6	0.5	0.0001	Sig.
	Pos tttt	4.8	0.9		
IMT	Pre ttt	3.7	0.7	0.0001	Sig.
	Post ttt	5.05	0.7		

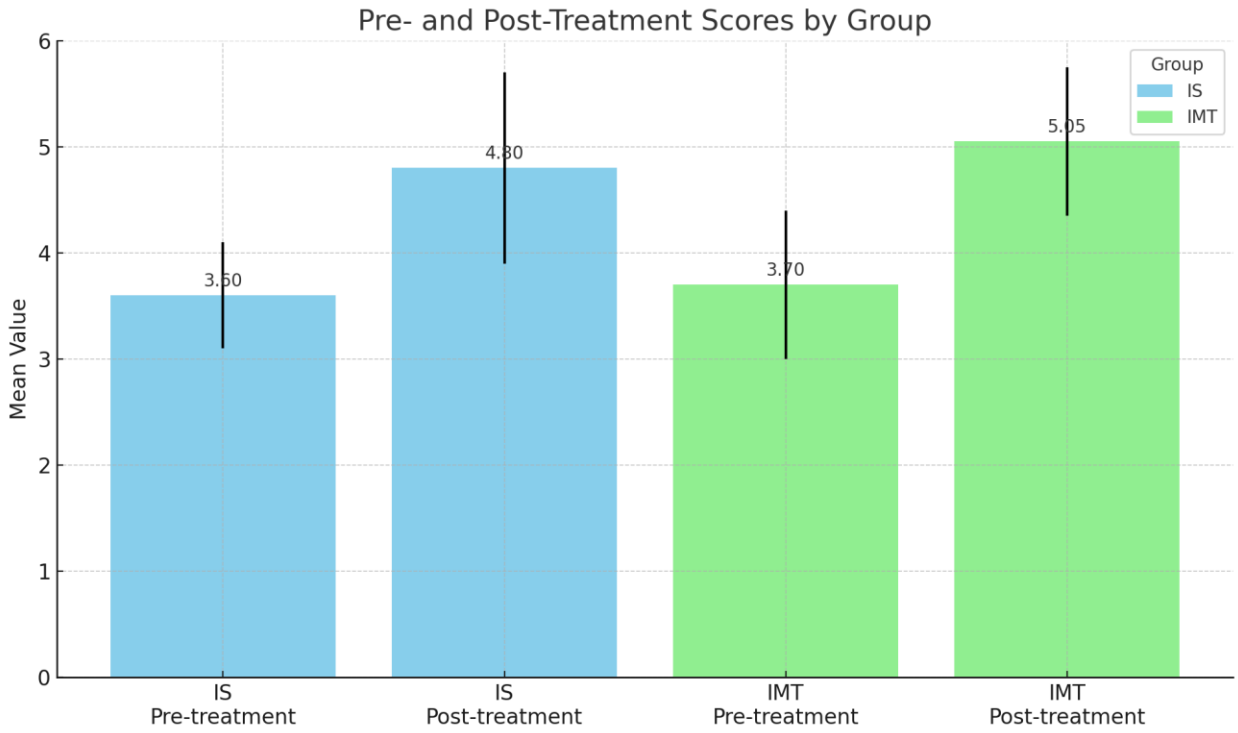

Figure 1 pre and post treatment evaluation results

DISCUSSION

This study demonstrated a statistically significant improvement in diaphragmatic excursion following CABG surgery in both the IS and IMT groups. This finding reinforces the value of incorporating respiratory training modalities in postoperative care. While IMT resulted in a slightly greater mean increase in diaphragmatic excursion, the difference between groups was not statistically significant, suggesting comparable clinical efficacy.

These outcomes are aligned with prior research. For instance, Hulzebos et al. (2006) and Kendall et al. (2018) reported similar improvements in pulmonary function and reduction in postoperative pulmonary complications with IMT. Likewise, studies supporting IS (e.g., Carvalho et al., 2011) emphasized its role in promoting deep breathing and preventing atelectasis, especially in the early postoperative phase.

Our results also showed that patients in the IS group reported higher adherence and comfort, likely due to the simplicity of use and visual feedback, while those in the IMT

group required more adaptation, which may have influenced compliance. This could partially explain the lack of significant difference despite the trend toward greater excursion in the IMT group.

Importantly, the use of ultrasound allowed for precise, non-invasive tracking of diaphragmatic movement. This strengthens the clinical relevance of our findings, supporting ultrasound as a practical tool for monitoring rehabilitation progress.

In summary, although both interventions significantly enhanced diaphragmatic excursion, individual patient factors such as comfort, compliance, and physical ability may guide the choice of modality. Our results support the integration of either IS or IMT into postoperative protocols, with potential consideration for personalized or combined approaches.

Conclusion

Both IS and IMT significantly improve diaphragmatic excursion after CABG surgery, with no major difference in effectiveness. IS is simple and widely accepted, while IMT offers focused training for patients with weak inspiratory muscles. Clinicians should choose based on individual patient needs. Future research should examine combined use and long-term benefits.

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