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Comparative Study of Incentive Spirometer and Active Cycle Breathing Technique in Improving FEV1/FVC in Post CABG Patients Phase-1

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ABSTRACT

Background: Following coronary artery bypass graft (CABG) surgery, patients often develop lung complications like collapsed lung segments and reduced lung capacity, leading to low blood oxygen and breathing difficulties that impede recovery. Incentive spirometry (IS) and active cycle of breathing techniques (ACBT) are physiotherapy methods used to improve lung function post-surgery. A Phase 1 trial assessed the safety and feasibility of IS and ACBT in CABG patients, specifically looking at their impact on the FEV1/FVC ratio. Both methods significantly improved lung function and reduced breathlessness, with ACBT showing slightly better results. No safety issues were observed, indicating both techniques are safe and feasible. Larger studies are needed to confirm these findings and explore long-term benefits, suggesting that incorporating IS and ACBT into post-CABG care could improve recovery and lower complication rates.

Objective: the objective of the study is to compare the safety and feasibility of IS and ACBT in improving forced expiratory volume in one second to forced vital capacity ratio (FEV1/FVC) in post-coronary artery bypass graft (CABG) patients, while exploring their effectiveness in improving pulmonary function parameters.

Methodology: A cohort of post-CABG patients was subjected to either IS or ACBT during Phase 1 rehabilitation. Safety and feasibility were evaluated alongside changes in pulmonary function parameters (FEV1, FVC, PEFR) and perceived breathlessness (Modified Borg Scale). Statistical analysis was conducted to compare the outcomes between the two intervention groups.

Results: The study found that Active Cycle of Breathing Techniques (ACBT) resulted in higher mean FEV1 (3.68 ± 0.96 L) and FVC (4.20 ± 0.87 L) compared to Incentive Spirometry (FEV1: 3.30 ± 1.13 L, FVC: 3.75 ± 0.94 L). ACBT also showed greater PEFR (6.81 ± 1.89 L/s) and lower Modified Borg Scale scores for breathlessness (4.07 ± 0.35) than Incentive Spirometry (PEFR: 5.76 ± 2.02 L/s, Borg Scale: 4.89 ± 1.47), indicating superior outcomes in pulmonary function and reduced breathlessness.

Conclusion: Incorporating IS and ACBT into postoperative care protocols for CABG patients can significantly enhance recovery by improving pulmonary function and reducing breathlessness. Larger trials are warranted to confirm these findings and explore long-term benefits, but this Phase 1 trial lays the groundwork for future research in this area.

Keywords: CABG, Incentive Spirometerer, Active Cycle of Breathing Techniques, FEV1/FVC, Postoperative Pulmonary Complications, pulmonary function, breathlessness, rehabilitation

INTRODUCTION

Coronary artery bypass graft (CABG) is a common surgical treatment for myocardial ischemia, involving grafting a patient's artery or vein from the aorta to bypass blockages and restore blood flow to the heart. It's a major surgery with established benefits for patients with significant coronary artery disease, and outcomes have improved over time despite patients having higher risk profiles. Globally, over 800,000 CABG surgeries are performed annually, with ongoing advancements in techniques[1]. In India, where coronary artery disease is prevalent and tertiary care is increasingly accessible, CABG is used to improve cardiac function. CABG is typically recommended for severe blockages or after failed percutaneous coronary intervention (PCI). Preoperative physical therapy is important as its absence increases the risk of postoperative pulmonary complications, which can arise from factors like anesthesia and the surgical procedure itself.[2] Exercise training beforehand can improve physical fitness and the ability to tolerate surgical stress, and physiotherapy techniques can enhance physical endurance and respiratory function.[3]

Post Surgery Phase-1.

- Phase I of rehabilitation occurring in the hospital is designed to mobilize the patient as soon as possible and to help the patient regain independence in daily life activities.[4]

Different preoperative exercises help patients manage the stress of the procedure and the recovery period as well as enhance their physical condition and fitness such as

- Incentive spirometer
- Active cycle breathing technique
- Respiratory Muscle Training
- Endurance Training
- Early Mobilization after surgery
- Relaxation therapy

It takes 6-8 weeks for the sternum to heal, physiotherapists show the patient the safest ways to lift and move their body, including rolling and sitting in bed.[5]

Incentive spirometer is a medical device that facilitates sustained maximal inspiration (SMI) with incorporated visual indicators performance (inspiratory effort) in order to aid the therapist in coaching the patient to optimal performance and likewise patients uses this visual feedback to monitor their own efforts. The device gives the individual visual feedback regarding flow and volume and also prevents and reverses atelectasis when used appropriately and regularly. The visual dimension of the therapy serves as a motivation or goal for the patient to try to meet by repeating the maximal effort frequently. The goal of an incentive spirometer is to help patients take sustained, slow, deep breaths, similar to natural sighing. These devices offer visual feedback to confirm proper flow or volume is reached. The technique involves a sustained maximal inspiration (SMI), which is a slow, deep breath from the resting lung volume up to total lung capacity, held for at least 5 seconds.[6]

There are typically two types of incentive spirometer, namely:

- Flow-oriented incentive spirometer (Triflow Device) - Has three chambers 3.63with one ball in each chamber. Capacity up to 1200ml.
- Volume-oriented incentive spirometer - Has one-way valve with capacity up to 4000ml. Current evidence tells us that using this type of spirometer requires lesser work of breathing and improves diaphragmatic function.[6] Using this device improves pulmonary function better compared to Triflow.[7]

Active cycle breathing technique (ACBT) Active cycle of breathing techniques (ACBT) is an active breathing exercise patients can perform to mobilize and clear lung secretions and improve

overall lung function. This adaptable technique can be combined with positioning and used by most patients. Its components can be used separately or as a cycle, depending on the individual's needs. Once taught, patients can perform ACBT independently without a physiotherapist and it requires no special equipment. ACBT helps to loosen and clear lung secretions (reducing chest infection risk), improve lung ventilation, and make coughing more effective.[8]

ACBT involves three main phases: Breathing Control (relaxation), Deep Breathing Exercises (lung expansion), and Huffing or Forced Expiratory Technique (FET) to move secretions. The technique can be adapted, and manual techniques or positive pressure can be added to aid secretion removal. A study showed ACBT with routine chest physiotherapy improved oxygen levels, heart rate, and pain after CABG.[9]

Breathing Control: This phase relaxes airways and eases wheezing/tightness after coughing or breathlessness. It's a resting period between active exercises, and closing the eyes can enhance relaxation. It's crucial to use breathing control between the other ACBT components.[10]

Deep breathing exercises or thoracic expansion exercises:
Deep breathing thoracic expansion exercises are deep breathing exercises that focus on inspiration[21] and help to loosen secretions on the lungs.[22] Inspiration is active and usually combined with a three-second, end-inspiratory hold before a passive, relaxed and unforced expiration.[11]

Huffing (FET): This technique moves secretions mobilized by deep breathing towards the mouth, using exhalation through an open mouth and throat instead of coughing. It moves sputum from small to large airways for easier removal by coughing.[12] There are two types:

- Medium Volume Huff: For lower airway secretions. Take a normal breath in, then a long, active breath out until lungs feel empty (like steaming a mirror).
- High Volume Huff: For upper airway secretions. Take a deep breath in, open mouth wide, and huff out quickly (1-2 times). Listen for crackles, then cough if sputum is ready to be expelled.[13]

Avoid excessive coughing as it can be tiring and ineffective. Repeat the ACBT cycle for about 10 minutes or until the chest feels clearer. Small, long huffs move sputum from lower down, while big, short huffs move it from higher up. Use the appropriate huff when secretions feel ready to be expelled.[14]

Coughing: Incorporate coughing if huffing alone doesn't clear sputum. Avoid prolonged coughing, which can be tiring and cause breathlessness or throat/chest soreness. Only cough if sputum can be easily cleared; otherwise, return to the beginning of the ACBT cycle.[9]

METHODOLOGY

Subjects included in the study informed about the study and given consent were allotted and assigned to either Active cycle breathing technique or Incentive spirometer group. 15 subjects in each group. 30 small chits were used, with fifteen pieces had the word “Group A- Active cycle breathing technique” and other fifteen pieces had the word “Group B-incentive spirometer”. All the pieces of paper were tightly folded and placed in a box. After shaking the box thoroughly each Subject was called forward to pick up a chit and went to the allotted group. As this study includes human subjects Ethical Clearance is obtained from the Ethical Committee of KTG College of Physiotherapy and KTG hospital, Bangalore as per the ethical guidelines for Bio-medical research on human subjects, 2000 ICMR, New Delhi. Comparative study of incentive spirometer and active cycle breathing technique in improving FEV1/FVC in post

CABG patients' phase-1. The subjects in group A and B received the respective intervention as stated below.

Procedure of Pre-Intervention:
Group A (n=15)
Group A participants received an explanation of the Active Cycle Breathing Technique and its effects. Prior to performing the technique, their baseline respiratory function was assessed using the Modified Borg's scale and Pulmonary Function Tests (PFTs).

Active Cycle Breathing Technique:
The study will utilize the Active Cycle Breathing Technique (ACBT) with patients in a relaxed, half lying position on the bed. The therapist will provide instruction and guidance while standing beside the patient.
Position of the patient: relaxed half lying position.
Position of the therapist: Standing beside the patient.
Procedure: Patient is asked to do several minutes of relaxed diaphragmatic breathing exercise (breathing control). This is a warm-up exercise that helps patient to relax and teaches them to use their diaphragm for deeper breaths. Now instruct the patient to lie down comfortably or sit upright with good posture. Place one hand on your chest and the other on your abdomen. Breathe in slowly through your nose for 4 seconds, feeling belly rise (not chest). Exhale slowly through pursed lips for 6 seconds, feeling your belly sink. Repeat for several minutes. Then patient is asked to take 3-4 active deep inspiration with passive relaxed exhalation (Thoracic expansion exercises), followed by relaxed diaphragmatic breathing (breathing control). The patient is asked to feel the secretions entering the larger 22 central airway, and then to do 2-3 huffs at higher volume and then relaxed breathing control. The cycle is repeated 2-4 times as per patient's tolerance.[17,18]
Frequency of treatment will be 20 minutes per session, twice a day, 3 days per week. And duration of the treatment will be 4 weeks.

Fig 1: Diaphragmatic breathing technique (inhalation phase)

Fig 2: Diaphragmatic breathing technique (exhalation phase)

Group B (n=15)

In Group B, patients were informed about Incentive Spirometry and its benefits. Before using the technique, their respiratory function was assessed using the Modified Borg's scale and Pulmonary Function Tests (PFTs).

Incentive Spirometer:

This group will undergo Incentive Spirometry (IS) therapy in a comfortable, half-lying position with relaxed shoulders. The therapist will be positioned for optimal guidance while standing beside the patient.

Position of the patient: half lying position.

Position of the therapist: standing beside the patient.

Procedure: Patients were asked to sit upright with the Incentive Spirometer held in an upright position, ask the subject to normally exhale and place their lips tightly around the mouthpiece. To achieve a Slow Sustained Maximal Inspiration (SMI), inhale at a sufficient rate to raise only the ball in the first chamber, Initially the flow rate was maintained at 200cc/sec as marked on the spirometer and gradually it was increased according to the capacity of the patient. While the ball in the second chamber remains at rest. For a higher flow rate, inhale at a rate sufficient to raise the first and second balls, while the ball in the third chamber remains at rest. Exhale after performing the exercise, remove the mouthpiece from your lips and exhale normally. Cycles were repeated for treatment duration of 15 min.

Frequency of treatment will be 20 minutes per session, twice a day, 3 days per week. And duration of the treatment will be 4 weeks.[12,13]

Fig 3: Incentive Spirometer inhalation phase

Fig 4: Incentive Spirometer exhalation phase

OUTCOME MEASUREMENTS

Pre and post scores of all the patients will be assessed using following outcome measures:

MODIFIED BORG'S SCALE

Modified Borg's Scale is used to determine exercise intensity, monitor progress, and guide exercise type for cardiac and other rehabilitation patients. The original Borgs scale (6-20) correlates with heart rate (number x 10 = training heart rate). A revised version, the borg CR10 scale or Modified Borg Dyspnea scale, often used for breathlessness, chest pain, and musculoskeletal pain, particularly for specific body sensations like muscle pain or pulmonary responses.[15] This simple numerical scale requires participants to rate their overall exertion during activity, considering physical stress and fatigue, while disregarding localised issues like leg pain or breathlessness. The chosen number reflects exercise intensity, allowing adjustment of movement speed. The scale is quick to complete and can be self or researcher-administered at various times.[15]

PULMONARY FUNCTION TEST

Pulmonary function tests, or PFTs, measure how well the lungs work. For some of the test measurements, patients can breathe normally and quietly. Other tests require forced inhalation or exhalation after a deep breath. Sometimes, they will be asked to inhale a different gas or a medicine to see how it changes test results.[16]

Spirometry Measures the rate of air flow and estimates lung size. For this test, client will breathe multiple times, with regular and maximal effort, through a tube that is connected to a computer. Some people feel lightheaded or tired from the required breathing effort. The most commonly used measures include the forced vital capacity (FVC), the forced expiratory volume in one second (FEV1), and the ratio of the two (FEV1/FVC), which should be about 80% in normal patients. An FEV1/FVC <80% suggests obstructive lung disease, while restrictive lung disease typically has normal or increased FEV1/FVC. Other useful data from spirometry include measures of flow, eg peak inspiratory flow (PIF) and peak expiratory flow (PEF).[17]

Forced Vital Capacity

Forced vital capacity (FVC) is a critical measure in pulmonary function tests (PFTs) used to assess lung health. It represents the total volume of air that can be forcefully exhaled from the lungs after taking the deepest breath possible. This measurement is fundamental in diagnosing and monitoring respiratory conditions such as asthma, chronic obstructive pulmonary disease (COPD), and restrictive lung diseases.[18]

Measurement Process:

The patient takes the deepest breath possible. Patient then exhales as forcefully and completely as possible into a spirometer. The spirometer records the volume of air exhaled over time.

1. **Importance in Pulmonary Function Testing**:

- FVC is one of the primary indicators of lung function.
- It helps in differentiating between obstructive and restrictive lung diseases.
- It is used to monitor disease progression and response to treatment.[16]

2. **Interpreting FVC Results**:

- **Normal FVC**: Indicates healthy lung function.
- **Reduced FVC**: Can suggest restrictive lung diseases, where lung expansion is limited.
- **Comparison with FEV1**: Forced Expiratory Volume in the first second (FEV1) is often compared with FVC to diagnose obstructive lung diseases like COPD. The FEV1/FVC ratio is crucial for this purpose.[19]

3. **Clinical Relevance**:

- FVC values are influenced by age, sex, height, and ethnicity.
- Reduced FVC can be seen in conditions such as pulmonary fibrosis, interstitial lung disease, and neuromuscular disorders affecting breathing.[20]

Forced Vital Capacity values

1. **Normal FVC Values:**

- **Men:** Typically, normal FVC values for men range from about 4.0 to 5.0 Liters.
- **Women:** Normal FVC values for women generally range from about 3.0 to 4.0 Liters.

2. **Percentage of Predicted Values:**

- Normal FVC: Greater than or equal to 80% of the predicted value.
- Mild Reduction: 70% to 79% of the predicted value.
- Moderate Reduction: 50% to 69% of the predicted value.
- Severe Reduction: Less than 50% of the predicted value.

Forced expiratory volume at 1st second (FEV1):

Forced expiratory volume is measured by spirometer. Forced expiratory volume is the maximal flow achieved during expiration at

the first second delivered with a maximal force starting from maximal lung function.
Subjects will be briefed about the machine and subject are made to relax and seated for the test.

- Subject will be informed to take a deep breath through nose and place the mouth piece in mouth and nose clip will be placed by the therapist after inhalation.
- Subject is informed to blow out forcefully into the apparatus and keep the breath going for at least 5 seconds, followed by maximal inhalation of air through mouth.
- Procedure is repeated for at least 3 attempts, and the average of the best attempts will be considered for the study.
- FEV1 is calculated by converting the spirometer reading to a value of what would be predicted as normal based on standardization that is calculated for your height, age, gender, and race.
- Before and after implementation of both the breathing exercises, FEV1 values will be recorded.

FEV1 values define the degree of obstruction:

- FEV1 greater than 80% of predicted = normal.
- FEV1 65% to 79% of predicted = mild obstruction.
- FEV1 50% to 64% of predicted = moderate obstruction.
- FEV1 less than 50% of predicted = severe obstruction.[21]

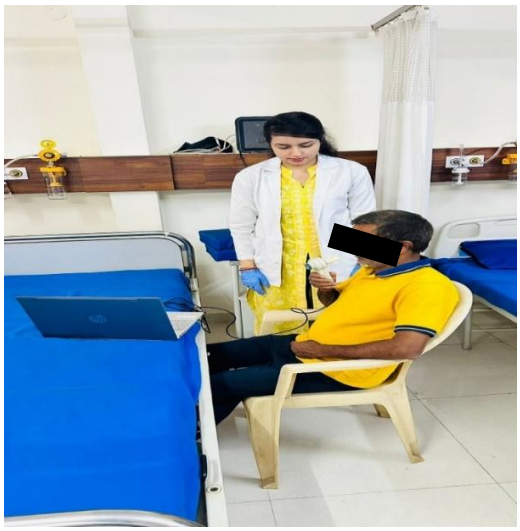


Fig 5: Using spirometer apparatus (inhalation)

Fig 6: Using spirometer apparatus (Exhalation)

Peak Expiratory Flow Rate The peak expiratory flow rate (PEFR) test measures how fast a person can exhale. The PEFR test is also called peak flow. This test is commonly performed at home with a handheld device called a peak flow monitor. The PEFR test does not need much preparation. Patient must loosen any tight clothing that might prevent you from breathing deeply. And to make sure that patient has to stand or sit up straight while taking the test.

Peak expiratory flow monitor is used to perform the PEFR test. This is a handheld instrument with a mouthpiece on one end and a scale on the other. When you blow air into the mouthpiece a small plastic arrow moves. This measures the airflow speed.

Procedure to perform PEFR test:

- Instruct the patient to breathe in as deeply as they can.
- Now instruct the patient to blow into the mouthpiece as quickly and as hard as they can. And not to put their tongue in front of the mouthpiece.
- And have to do the test three times.
- Should note the highest speed of the three.[22]

RESULTS AND INTERPRETATION

TABLE 1: Comparison of AGE distribution between ACBT and Incentive spirometer

		ACBT	INCENTIVE SPIROMETER	Z VALUE (MANN WHITNEY U TEST)	P VALUE
AGE	MEAN	47.63	45.62	0.04	0.96
	SD	1.25	0.86		

P<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)

Mann Whitney U test did not report statistically significant difference in mean age between the groups (p>0.05).The descriptive statistics for the age of the 30 participants are presented in Table 4. The participants' ages ranged from a minimum of 29 years to a maximum of 60 years, with a mean age of 47.63 years (SD = 7.859). This indicates that the average age of the participants is approximately 47.63 years, with a standard deviation of 7.859 years, reflecting the variability of ages within the sample. The relatively wide age range (29 to 60 years) suggestsa diverse age distribution among the participants.

Graph 1: Comparison of AGE distribution between ACBT and Incentive spirometer

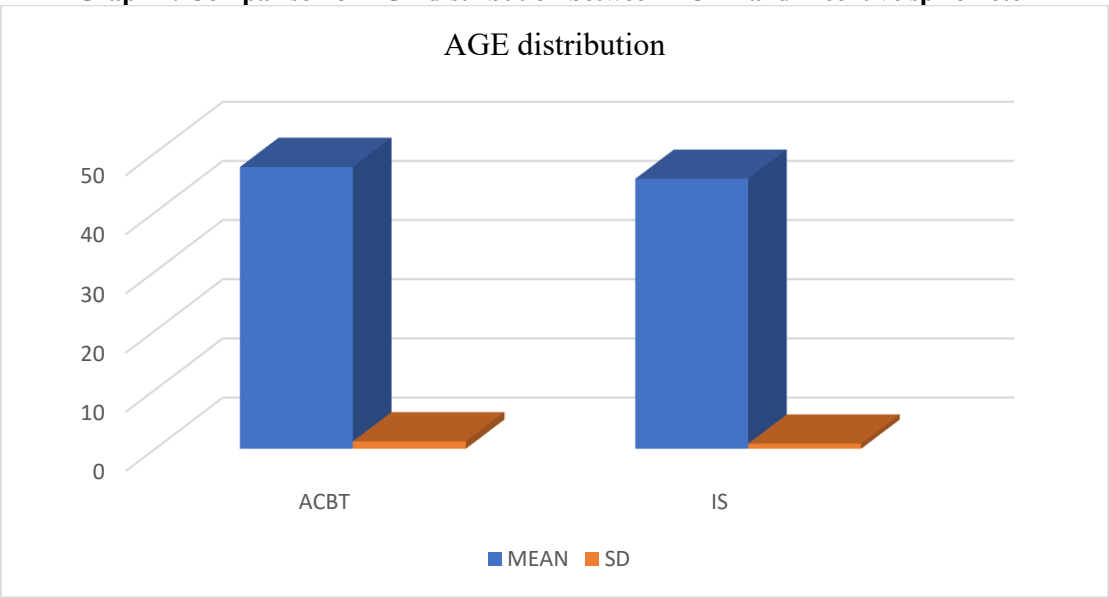


TABLE 2: Comparison of Weight between ACBT and Incentive Spirometer Groups

		ACBT	INCENTIVE SPIROMETRY	Z VALUE (MANN WHITNEYU TEST)	P VALUE
WEIGHT	MEAN	54.64	52.35	0.46	0.69
	SD	10.53	9.87		

P<0.05 is statistically significant (Shapiro Wilkinson test, p<0.05)

Mann Whitney U test did not report statistically significant difference in mean weight between the groups (p>0.05). The comparison of weights between the ACBT group (M = 54.64, SD = 10.53) and the Incentive Spirometry group (M = 52.35, SD = 9.87) yielded a Z value of 0.46 and a p valueof 0.69, as shown in Table 5. The p value of 0.69 indicates that there is no statistically significant difference in weight between the two groups. Therefore, it can be concluded that weight did not significantly influence the outcomes between the ACBT and Incentive Spirometry groups in this study.

Graph 2: Comparison of Weight between ACBT and Incentive Spirometer Groups

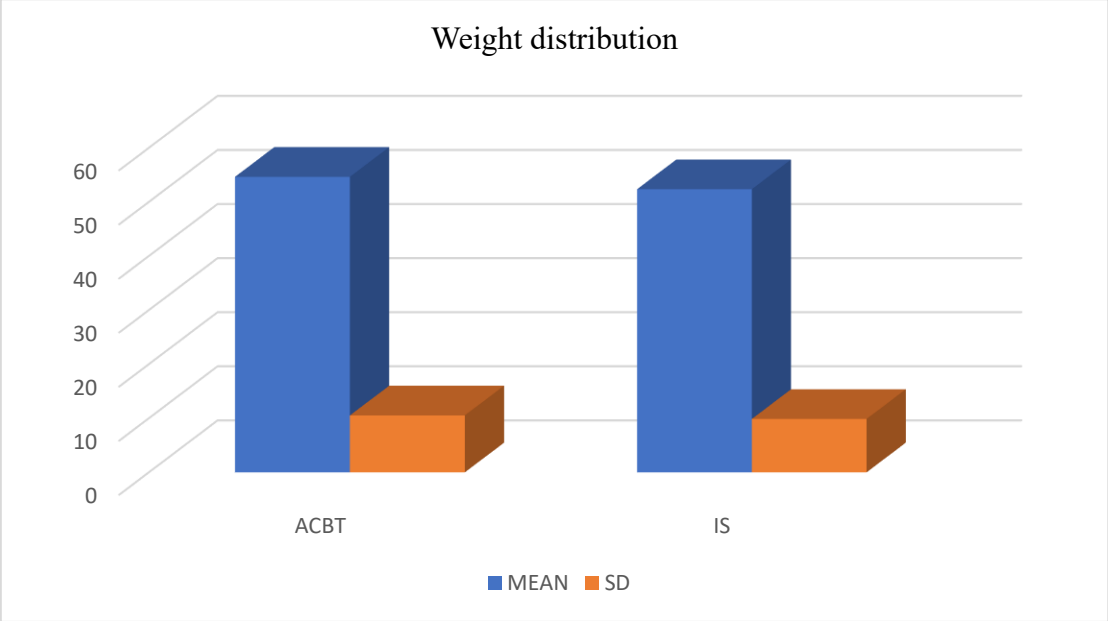


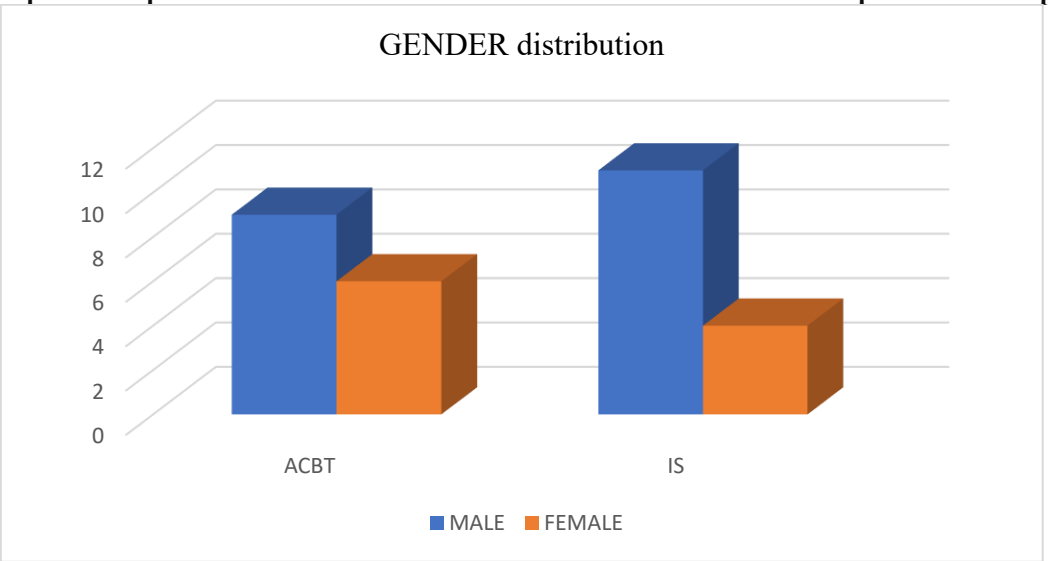
Table 3: Comparison of Gender Distribution between ACBT and Incentive spirometer Groups

		ACBT	IS	X^2VALUE	P VALUE
GENDER	MALE	9(31.8%)	11(31.8%)	0.01	0.97
	FEMALE	6(68.2%)	4(68.2%)		

P<0.05 is statistically significant

CHI SQUARE test did not report statistically significant difference in frequency in gender between the groups (p>0.05) The comparison of gender distribution between the ACBT group and the Incentive spirometry group shows that in both groups, 68.2% of the participants were male and 31.8% were female. The Chi-square test yielded an X^2 value of 0.01 with a p value of 0.99. The highp value indicates that there is no statistically significant difference in the gender distribution between the two groups. Therefore, gender was evenly distributed across the ACBT and Incentive spirometry groups in this study, and it did not significantly impact the comparison of outcomes between these two groups.

Graph 3: Comparison of Gender Distribution between ACBT and Incentive spirometer Groups



The pulmonary function test results for the Active Cycle of Breathing Techniques (ACBT) indicate significant improvements in several key respiratory parameters from pre-test to post- test measurements.

TABLE 4: Pre and Post PFT for ACBT

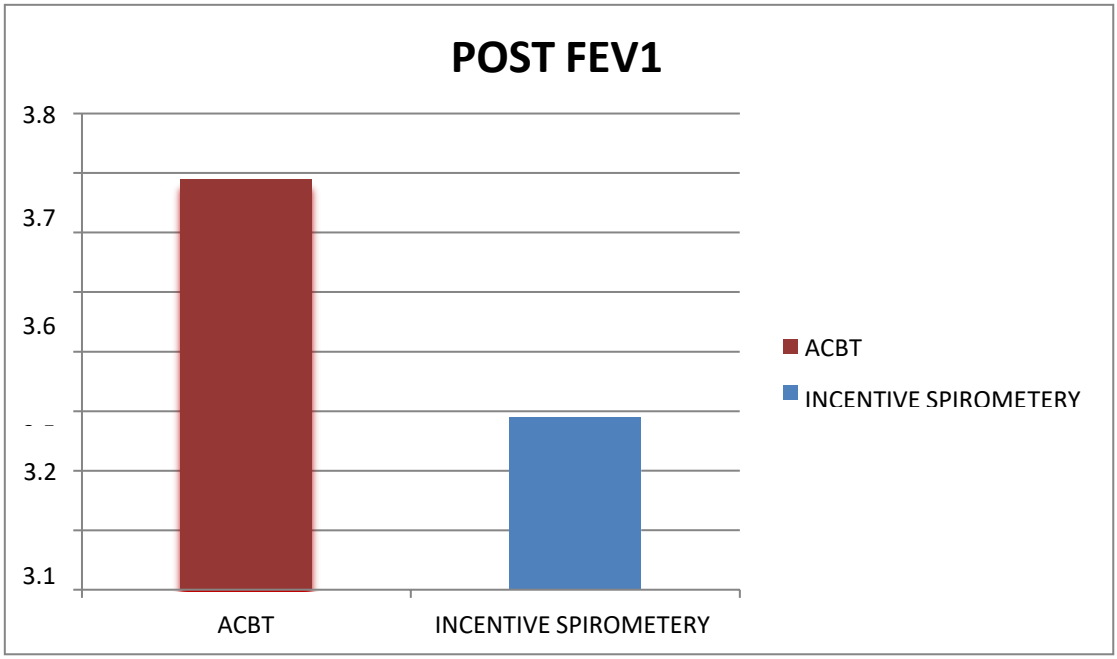
	FEV1		FVC		FEV1/FVC		PEFR		MBS	
	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST
Mean	3.32± 0.97	3.68± 0.96	3.87± 0.87	4.20± 0.87	87.71 ±9.13	85.66± 11.68	5.88± 1.77	6.81± 1.89	4.23± 1.43	4.89± 1.47

Interpretation

Forced Expiratory Volume in one second (FEV1) increased from a pre-test mean of 3.32 Liters (SD = 0.97) to a post-test mean of 3.68 Liters (SD = 0.96). This suggests an enhancement in the patients' ability to expel air from the lungs in one second after the intervention. Forced Vital Capacity (FVC) also showed a notable increase, with a pre-test mean of 3.87 liters (SD = 0.87) compared to a post-test mean of 4.20 liters (SD = 0.87). The FEV1/FVC ratio demonstrated a slight decrease from 87.71% (SD = 9.13) pre-test to85.66% (SD = 11.68) post-test. While this ratio decreased, the absolute values of FEV1 and FVC both increased, suggesting that the overall lung function improved, although the proportional relationship between the two measures slightly diminished.

Peak Expiratory Flow Rate (PEFR) showed a significant rise from 5.88 liters/second (SD = 1.77) to 6.81 liters/second (SD = 1.89). This increase indicates that the maximum speed of expiration improved post-intervention, reflecting better airway clearance and respiratory muscle performance. Lastly, the Modified Borg Scale (MBS) scores, which measure perceived breathlessness, decreased from a pre-test mean of 4.23 (SD = 1.43) to a post-test mean of 4.89 (SD = 1.47). Lower scores on the MBS represent reduced breathlessness, suggesting that patients experienced less dyspnea following the ACBT intervention.

GRAPH 4a: COMPARIOSN OF POST FEV1 OF ACBT & INCENTIVE SPIROMETER



GRAPH 4b: COMPARIOSN OF POST FVC OF ACBT & INCENTIVE SPIROMETER

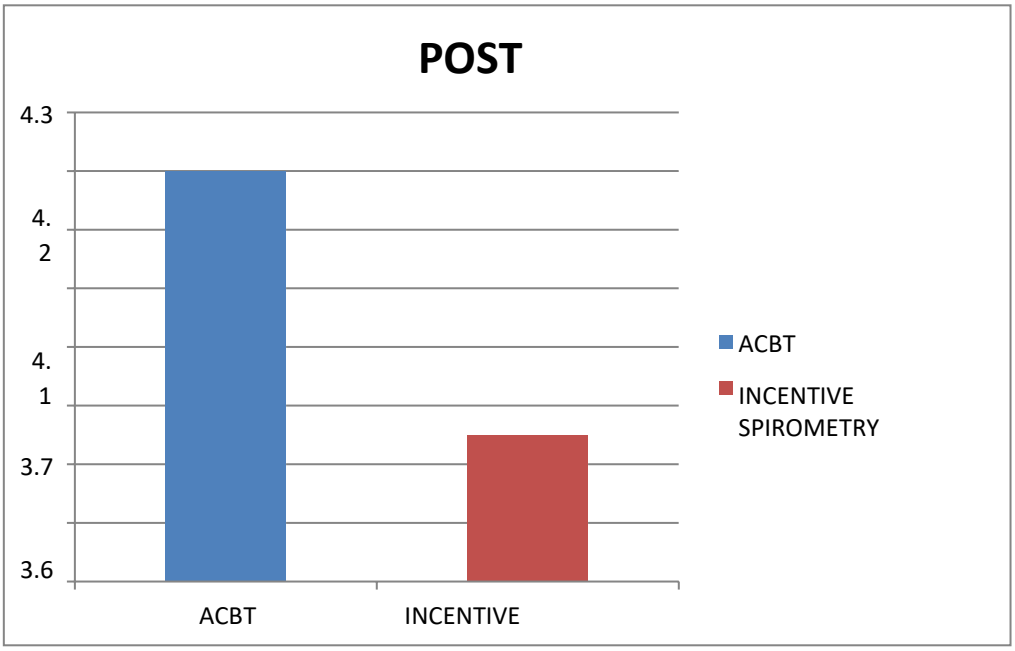


TABLE 5: Pre and Post PFT for Incentive spirometry

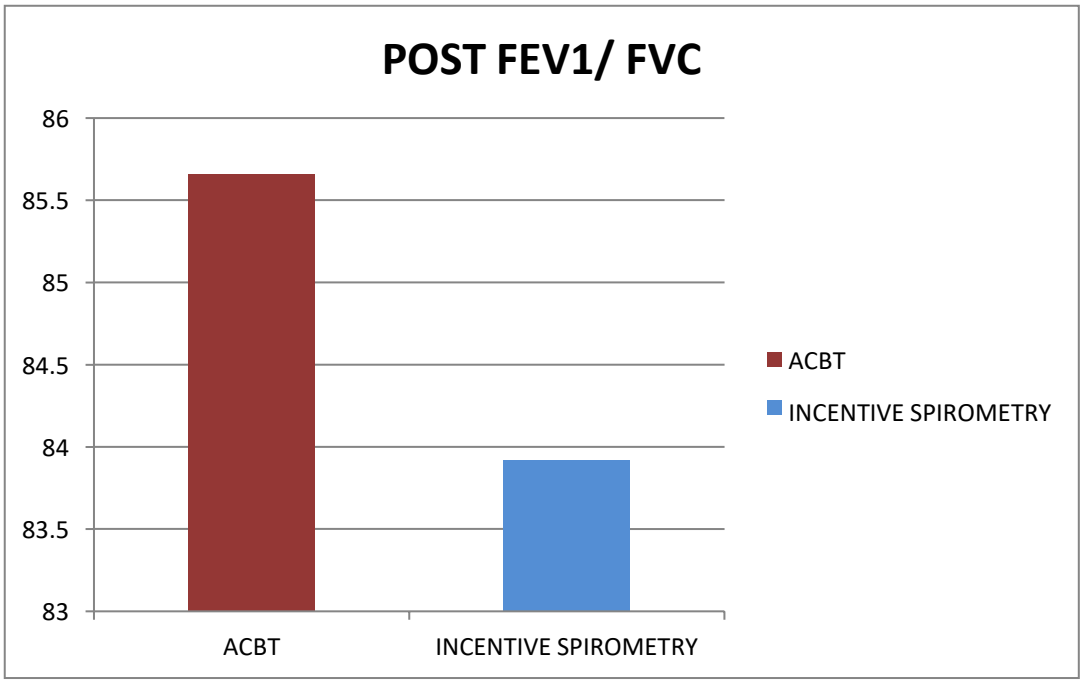
	FEV1		FVC		FEV1/FVC		PEFR		MBS	
	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST
Mean	3.09 ± 1.11	3.30 ± 1.13	3.53 ± 0.93	3.75± 0.94	81.41 ± 16.02	83.92 ± 16.42	5.43 ± 2.019	5.76± 2.015	3.88± 0.3431	4.07± 0.3456

Interpretation

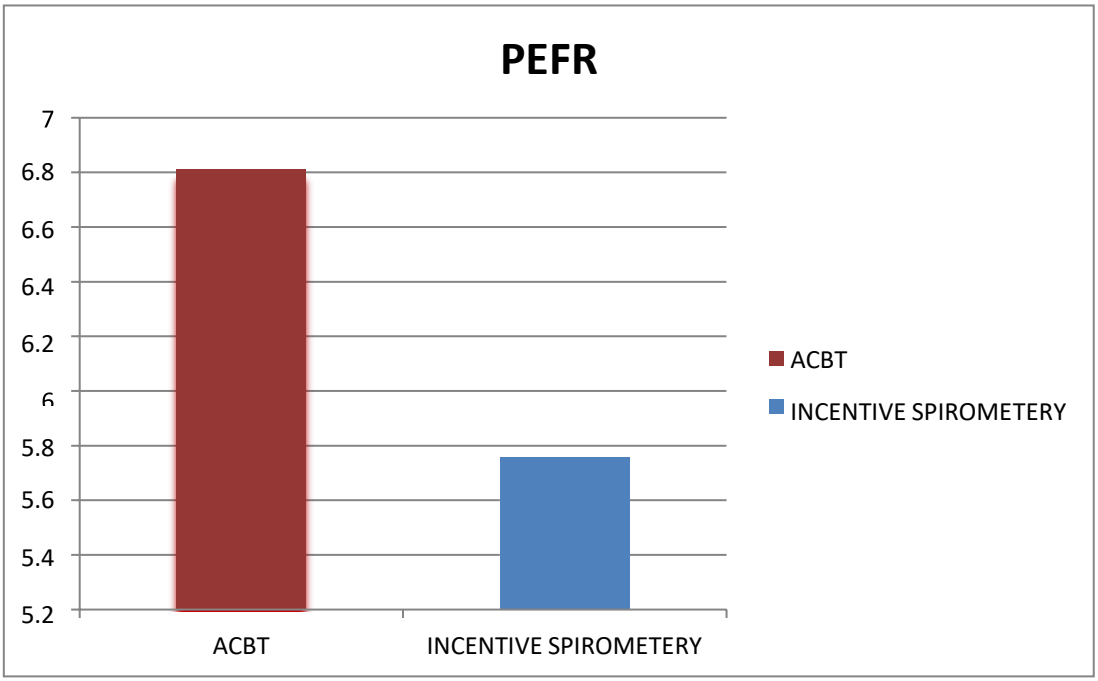
Following the intervention, participants showed slight improvements in several pulmonary function parameters. The mean Forced Expiratory Volume in one second (FEV1) increased from 3.09 to 3.30 liters, indicating better expiratory flow and lung function. The mean Forced Vital Capacity (FVC) rose from 3.53 to 3.75 Liters, suggesting increased lung volume and

capacity. The FEV1/FVC ratio also slightly improved from 81.41% to 83.92%, reflecting better overall pulmonary function. The mean Peak Expiratory Flow Rate (PEFR) increased from 5.43 to 5.76 liters per second, indicating enhanced maximum expiration speed and stronger expiratory muscles. However, the mean Modified Borg Scale (MBS) score increased from 3.88 to 4.07, suggesting a greater feeling of exertion after the intervention, possibly due to increased effort or improved physical capacity.

GRAPH 5a: COMPARIOSN OF POST FEV1/FVC OF ACBT & INCENTIVESPIROMETER



GRAPH 5b: COMPARIOSN OF POST PEFR OF ACBT & INCENTIVE SPIROMETRY



GRAPH 5c: COMPARIOSN OF POST MBS ACBT & INCENTIVE SPIROMETRY

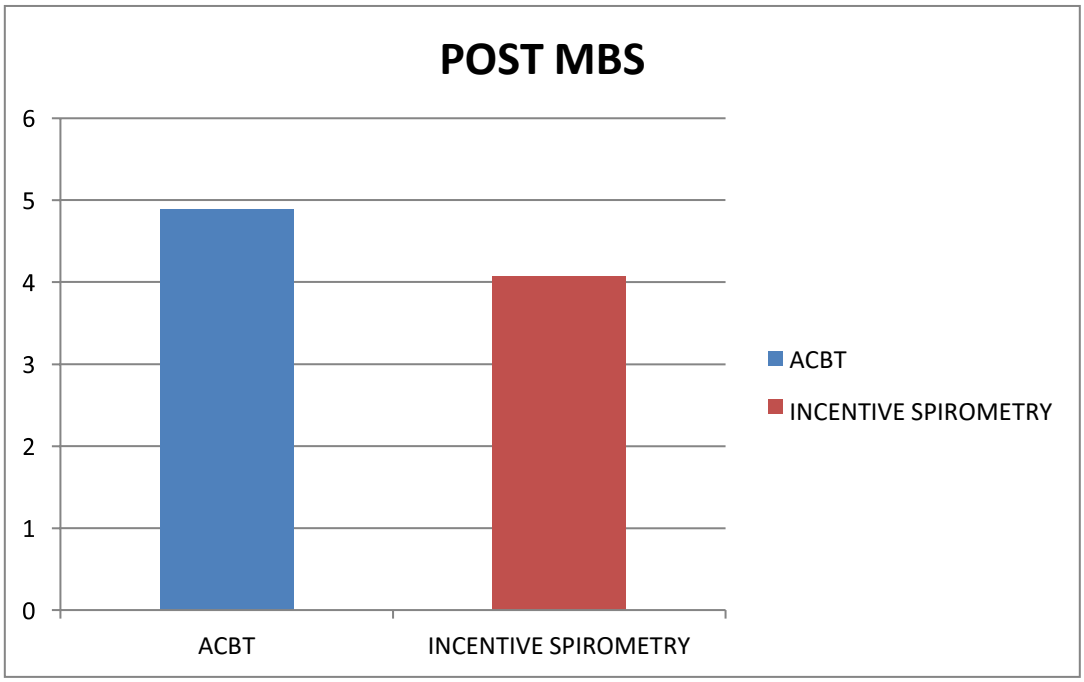


TABLE 6: P-Paired test for Post PFT values for ACBT and Incentive Spirometry

	FEV1		FVC		FEV1/FVC		PEFR		MBS	
	A	B	A	B	A	B	A	B	A	B
Mean	3.68± 1.13	3.03± 0.96	4.20± 0.87	3.75± 0.94	85.66± 11.68	83.92± 16.42	6.81± 1.89	5.76± 2.02	4.89± 1.47	4.07± 0.34

Values are expressed as Mean ± Standard Deviation (SD).

Post-treatment pulmonary function tests (PFTs) showed that Active Cycle of Breathing Techniques (ACBT) resulted in better respiratory parameters compared to Spirometry. Specifically, ACBT showed higher Forced Expiratory Volume in one second (FEV1) (M = 3.68, SD = 1.13 vs. M = 3.03, SD = 0.96), indicating a greater improvement in the amount of air forcefully exhaled in one second. Forced Vital Capacity (FVC) was also higher with ACBT (M = 4.20, SD = 0.87 vs. M = 3.75, SD = 0.94), suggesting ACBT is more effective at increasing the total exhaled air volume after a full breath. The FEV1/FVC ratio was slightly better with ACBT (M = 85.66, SD = 11.68 vs. M = 83.92, SD = 16.42). Peak Expiratory Flow Rate (PEFR) was significantly higher with ACBT (M = 6.81, SD = 1.89 vs. M = 5.76, SD = 2.02), indicating ACBT enhances the maximum speed of exhalation more effectively. Lastly, perceived breathlessness, measured by the Modified Borg Scale (MBS), was lower with ACBT (M = 4.07, SD = 0.34 vs. M = 4.89, SD = 1.47). Overall, ACBT appears to lead to greater improvements in key lung function measures and reduce perceived breathlessness compared to Spirometry.

TABLE 7: COMPARISON OF PRE & POST FVC, FEV1, FEV1/FVC, PEFR OF GROUP A (ACBT)

PRE VALUE	FVC in % Pred	FEV1 in % Pred	FEV1/FVC RATIO in % Pred	PEFR in % Pred
Mean	72.53	74.20	113.33	67.87
Std. Deviation	11.710	9.329	8.974	13.223
POST VALUE	**FVC in % Pred**	**FEV1 in % Pred**	**FEV1/FVC RATIO in % Pred**	**PEFR in % Pred**
Mean	83.20	86.93	121.73	79.13
Std. Deviation	11.785	9.430	10.620	14.141

The comparison of pre and post values for Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV1), FEV1/FVC ratio, and Peak Expiratory Flow Rate (PEFR) in Group A (ACBT) demonstrates significant improvements in pulmonary function following the intervention. Before the intervention, participants exhibited mean FVC and FEV1 percentages of predicted values at 72.53% and 74.20%, respectively, with a mean FEV1/FVC ratio of 113.33% and PEFR at 67.87% of predicted values. Post-intervention, there was a notable increase in these values, with FVC and FEV1 rising to 83.20% and 86.93%, respectively, and the FEV1/FVC ratio and PEFR reaching 121.73% and 79.13% of predicted values, respectively. These findings indicate enhanced lung capacity, airway patency, and expiratory flow rates following the intervention, suggesting a positive impact on respiratory function and potentially improved quality of life for participants undergoing ACBT.

GRAPH 7: COMPARISON OF PRE & POST FVC, FEV1, FEV1/FVC, PEFR OF GROUP A (ACBT)

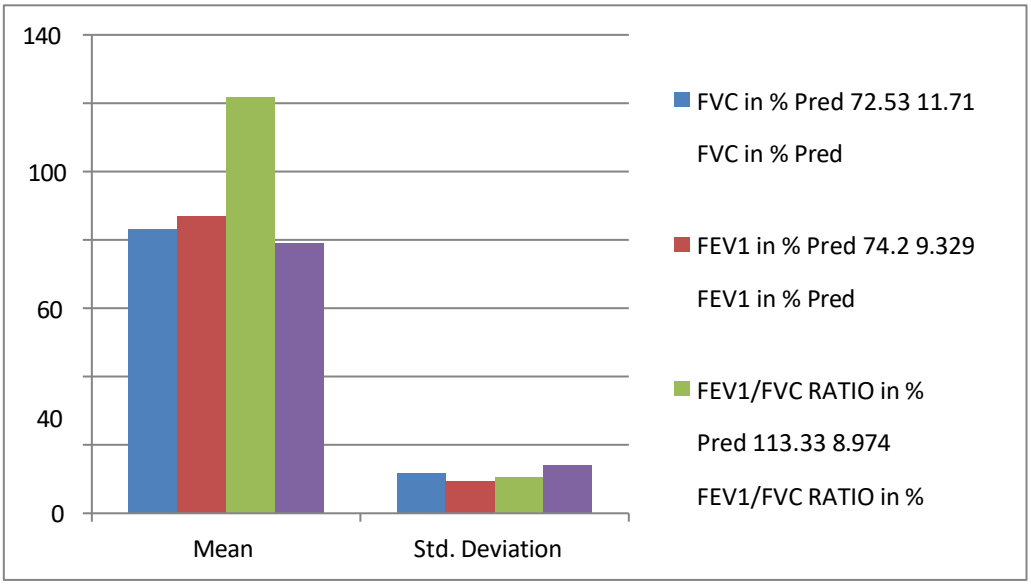


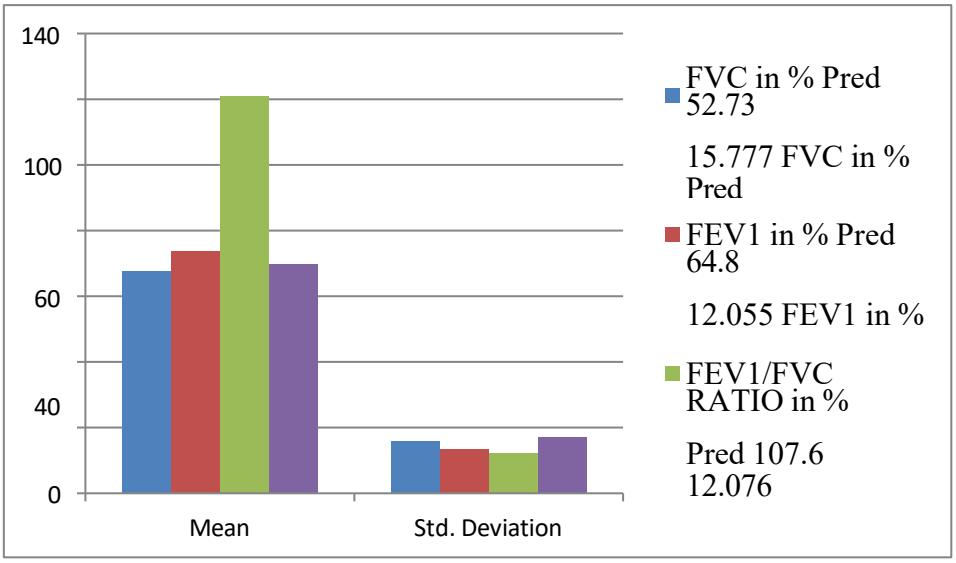
TABLE 8: COMPARISON OF PRE & POST FVC, FEV1, FEV1/FVC, PEFR OF GROUP B (INCENTIVE SPIROMETRY)

PRE VALUE	FVC in % Pred	FEV1 in % Pred	FEV1/FVC RATIO in % Pred	PEFR in % Pred
Mean	52.73	64.80	107.60	51.73
Std. Deviation	15.777	12.055	12.076	16.381
POST VALUE	**FVC in % Pred**	**FEV1 in % Pred**	**FEV1/FVC RATIO in % Pred**	**PEFR in % Pred**
Mean	67.73	73.80	120.80	69.73
Std. Deviation	15.818	13.337	12.178	16.897

the comparison of pre and post values for Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV1), FEV1/FVC ratio, and Peak Expiratory Flow Rate (PEFR) in Group B (Incentive Spirometry) highlights significant improvements in pulmonary function following the intervention. Before the intervention, participants exhibited mean pre-values of 52.73% predicted for FVC, 64.80% predicted for FEV1, 107.60% predicted for FEV1/FVC ratio, and 51.73% predicted for PEFR, with standard deviations of 15.777, 12.055, 12.076, and 16.381, respectively. After the intervention, these values increased to 67.73%, 73.80%, 120.80%, and 69.73% predicted for FVC, FEV1, FEV1/FVC ratio, and PEFR, respectively, with standard deviations of 15.818, 13.337, 12.178, and 16.897. These

changes demonstrate a statistically significant improvement in pulmonary function post-intervention, as indicated by the substantial increase in mean values across all parameters. The consistent standard deviations between pre and post values suggest a consistent spread of data around the means. Overall, these findings underscore the effectiveness of Incentive Spirometry in enhancing respiratory function and improving pulmonary health outcomes in the study participants

GRAPH 8: COMPARISON OF PRE & POST FVC, FEV1, FEV1/FVC, PEFR OF GROUP A (INCENTIVE SPIROMETRY)



SPSS version 26.0 was used for data analysis, with significance set at $p<0.05$. Descriptive statistics (mean, standard deviation) were calculated, and data normality was checked using the Shapiro-Wilkinson test. Between-group and within-group comparisons employed the Mann-Whitney U test, Wilcoxon Matched-Pair Test, and Chi-Square test to compare Active Cycle of Breathing Techniques (ACBT) and Incentive Spirometry in post-CABG patients. The Mann-Whitney U test showed no significant differences between the ACBT and Incentive Spirometry groups regarding age ($p = 0.96$), weight ($p = 0.69$), or gender distribution ($p = 0.97$). Post-treatment analysis revealed that ACBT resulted in significantly higher mean FEV1 (3.68 ± 0.96 liters vs. 3.30 ± 1.13 liters), FVC (4.20 ± 0.87 liters vs. 3.75 ± 0.94 liters), and PEFR (6.81 ± 1.89 liters/second vs. 5.76 ± 2.02 liters/second) compared to Incentive Spirometry. Additionally, the Modified Borg Scale (MBS) scores indicated less breathlessness in the ACBT group (4.07 ± 0.35) compared to the Incentive Spirometry group (4.89 ± 1.47). These results suggest that ACBT may lead to greater improvements in lung function and reduced breathlessness in patients after CABG surgery.

RESULTS

The data analysis was performed using SPSS software version 26.0. The significance level was set at $p<0.05$ for all tests. Descriptive statistics were calculated to determine the mean and standard deviation within each group. The normality of the data was assessed using the Shapiro- Wilkinson test. Inferential statistics, including the Mann-Whitney U test, Wilcoxon Matched Pair Test, and Chi-Square test, were used for between-group and within-group comparisons. The study compared the effects of Active Cycle of Breathing Techniques (ACBT) and Incentive Spirometry on post-Coronary Artery Bypass Grafting (CABG) patients. The Mann-Whitney U test indicated no statistically significant differences

between the two groups in terms of age (mean ages: ACBT = 47.63, Incentive Spirometry = 45.62, p = 0.96), weight (mean weights: ACBT = 54.64 kg, Incentive Spirometry = 52.35 kg, p = 0.69), or gender distribution (68.2% male and 31.8% female in both groups, p = 0.97). Post-treatment analysis revealed that ACBT resulted in higher mean Forced Expiratory Volume in one second (FEV1: 3.68 ± 0.96 liters) compared to Incentive Spirometry (3.30 ± 1.13 liters). Similarly, Forced Vital Capacity (FVC) was higher in the ACBT group (4.20 ± 0.87 liters) versus the Incentive Spirometry group (3.75 ± 0.94 liters). The Peak Expiratory Flow Rate (PEFR) also showed greater improvement with ACBT (6.81 ± 1.89 liters/second) compared to Incentive Spirometry (5.76 ± 2.02 liters/second). The Modified Borg Scale (MBS) scores indicated reduced breathlessness in the ACBT group (4.07 ± 0.35) compared to the Incentive Spirometry group (4.89 ± 1.47). Overall, these findings suggest that ACBT may lead to better improvements in pulmonary function and reduced breathlessness in post-CABG patients.

DISCUSSION

This study evaluated incentive spirometry (IS) and active cycle of breathing techniques (ACBT) for improving lung function (FEV1, FVC, PEFR) and breathlessness (modified Borg scale) in post-CABG patients during early rehabilitation. Both interventions significantly improved lung function and reduced breathlessness, supporting their effectiveness in postoperative recovery. IS might offer quicker gains in inspiratory volumes due to visual feedback, while ACBT could provide better overall lung clearance and sustained improvements. Both techniques were found to be safe and feasible for this patient population.

While both IS and ACBT are effective post-CABG, a combined approach leveraging IS's visual feedback and ACBT's comprehensive lung clearance may optimize outcomes. However, the study's small size and short duration limit long-term conclusions. Future research should involve larger, multi-center trials to validate these findings, assess long-term impacts and cost-effectiveness, and identify patient factors that predict better responses to each technique. This study supports incorporating IS and ACBT into routine postoperative care to improve recovery and reduce complications in CABG patients.

Physiotherapy is crucial for post-CABG recovery, addressing pain, mobility, and lung function. [1] Hong et al. (2018) noted significant physiotherapist time spent on mobilization and pain management, with peak pain on the first postoperative day decreasing by day four, though physiotherapy sessions could initially increase pain. While physiotherapists generally found pain management adequate for treatment, a balance is needed to optimize early mobilization. Commonly used physiotherapy techniques post-CABG include mobilization, deep breathing exercises, and incentive spirometry (Stephanie R. et al., 2012; Westerdahl et al., 2001).

While mobilization, deep breathing, and incentive spirometry (IS) are common post-CABG physiotherapy techniques, their adoption varies. Westerdahl's research showed no major differences between deep breathing techniques, with the blow bottle showing slightly better pulmonary function outcomes, highlighting the need for standardized guidelines. The effectiveness of IS in preventing postoperative pulmonary complications (PPCs) is debated, with some studies (Eltorai et al., 2019; Freitas et al., 2007) showing benefits with adherence reminders (reduced atelectasis, shorter ICU stays), while others (Crowe & Bradley, 1997; Overend et al., 2001) found no significant advantage over other physiotherapy. More large-scale trials are needed to clarify IS's role. Conversely, studies on Active Cycle of Breathing Techniques (ACBT) (Monisha R. & Muthukumar, 2018; Salehi Derakhtanjani et al., 2019) consistently demonstrate improved functional capacity and pulmonary parameters, suggesting ACBT as a key

component of post-CABG physiotherapy. [1] Anand et al. (2023) found home spirometry reliable and valid for long-term monitoring, potentially improving early detection of complications and reducing readmissions. Data analysis in these studies often uses SPSS version 26.0 with a significance level of $p<0.05$. Descriptive statistics showed similar baseline characteristics (age, weight, gender) between the ACBT and Incentive Spirometry (IS) groups. Post-treatment, the ACBT group exhibited statistically higher mean values for FEV1 (3.68 ± 0.96 liters), FVC (4.20 ± 0.87 liters), PEFR (6.81 ± 1.89 liters/second), and lower Modified Borg Scale scores (4.07 ± 0.35) compared to the IS group (FEV1: 3.30 ± 1.13 liters; FVC: 3.75 ± 0.94 liters; PEFR: 5.76 ± 2.02 liters/second; MBS: 4.89 ± 1.47). This suggests ACBT may lead to better improvements in pulmonary function and reduced breathlessness post-CABG. Within the Incentive Spirometry (Group B), statistically significant improvements were observed in mean predicted values from pre- to post-intervention for FVC (52.73% to 67.73%), FEV1 (64.80% to 73.80%), FEV1/FVC ratio (107.60% to 120.80%), and PEFR (51.73% to 69.73%). The consistent standard deviations indicate a similar data spread. These findings highlight the effectiveness of Incentive Spirometry in enhancing respiratory function in the study participants.

CONCLUSION

This study confirms that both incentive spirometry (IS) and active cycle of breathing techniques (ACBT) significantly improve lung function (FEV1, FVC, PEFR) and reduce breathlessness in post-CABG patients during early rehabilitation. While both are beneficial, ACBT showed slightly better outcomes in these parameters, possibly due to its comprehensive approach, whereas IS offers immediate visual feedback. Both are safe and feasible for clinical use, and a combined approach could be optimal. However, the study's small size and short duration necessitate larger, long-term, multicentre trials to validate these findings and explore cost-effectiveness and personalized rehabilitation strategies. Ultimately, integrating IS and ACBT enhances post-CABG recovery.

Limitation of the Study

Limitations of the study include its small sample size, which may limit the generalizability of the findings to a broader population. Additionally, the short duration of the study might not capture the long-term effects of the interventions or potential delayed adverse events. The study did not control for all potential confounding variables, such as variations in surgical techniques or preoperative respiratory status, which could affect the outcomes. Moreover, the study focused primarily on Phase 1 rehabilitation, warranting further investigation into the long-term efficacy and cost-effectiveness of the interventions in larger, multicentre trials.

Recommendation for future research

Increasing Sample Size: Conduct studies with larger, more diverse populations to improve the generalizability of the results. A larger sample size will help capture a wider range of variability and ensure the findings are more representative of the broader population. Extending Study Duration: Implement longer follow-up periods to monitor the long-term effects of the interventions and identify any delayed adverse events. Extended study durations will provide a more comprehensive understanding of the sustainability and potential risks associated with the treatments. Controlling for Confounding Variables: Design studies that account for potential confounding factors such as variations in surgical techniques, preoperative respiratory status, and other relevant variables. This can be achieved through randomized controlled trials or stratified analyses to isolate the effects of the interventions from other influencing factors. Exploring Different Phases of Rehabilitation: Expand the focus beyond Phase 1 rehabilitation to include subsequent phases. This will help determine

the long-term efficacy and progression of rehabilitation programs, providing a more holistic view of the patient recovery process. Evaluating Cost-Effectiveness: Conduct comprehensive cost-effectiveness analyses to determine the economic viability of the interventions. This includes assessing the cost in relation to the health benefits achieved over the long term, which is crucial for healthcare policy and decision-making. Multicentre Trials: Perform multicentre trials to validate the findings across different settings and populations. This approach enhances the external validity of the study results and ensures that the conclusions are applicable in various clinical environments.

Declaration by Authors

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