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Effect of Acapella versus Incentive Spirometry on Partial Pressure of Carbon Dioxide in Arterial Blood after Coronary Artery Bypass Graft Surgery: A Randomized Controlled Trial.

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ABSTRACT: Background: Patients undergoing coronary artery bypass grafting (CABG) are at increased risk for postoperative pulmonary complications, which may include pneumonia, atelectasis, bronchospasm, exacerbation of chronic obstructive pulmonary disease (COPD), pneumothorax, pleural effusion, and various upper respiratory tract conditions. (1) The Acapella method is used to improve lung volume and airway patency in the early postoperative period in patients who have undergone coronary artery bypass grafting (CABG).

Objectives: to evaluate and compare the effect of acapella and incentive spirometry on Partial Pressure of Carbon Dioxide (PaCO₂) after coronary artery bypass graft.

Method: In a randomized controlled study, the effects of acapella versus incentive spirometry were compared in two cardiac centers (the Iraqi center of heart disease and Ibn Al-Bitar Specialized Center) from December 8th, 2025, to June 23rd 3, 2026. after getting the Ethical Approval Committee under No:37 on March 25, 2025.informed written agreement was gotten from all participant were involved in the study. The researchers' recruited volunteers who had undergone coronary artery bypass grafting (CABG) and randomly separated them into two groups: a study group and a control group. A total of 85 patients take part in the study. The main outcomes were measurements of PaCO₂, were extracted from the patients' clinical records (ABGs), with the mean value calculated when the tests being conducted numerous times daily. PaCO₂ measured 10 hours after extubation when patient is stable, one day after extubation, and day three after extubation after the procedure. The data were analyzed and interpreted by means of the statistical software SPSS (version 26.0). Qualitative variables such as age, sex, level of education, occupation, and place of residence were statistically analyzed using frequencies and percentages. Numerical variables were statistically analyzed using mean and standard deviation. A p-value below 0.05 was measured statistically significant.

Results: The findings demonstrate significant reduction in PaCO₂ levels over the three measurement periods in the control group ($\chi^2= 15.630$, $p= 0.000$) with moderate effect

size (0.289); Incentive Spirometry group ($\chi^2= 19.513$, $p= 0.000$) with moderate effect size (0.325), and Acapella group ($\chi^2= 27.214$, $p= 0.000$) with large effect size (0.486).

Conclusions: our study results showed that both Acapella and Incentive spirometry were associated with improved PaCo₂ after Coronary Artery Bypass Graft, with Acapella showing the largest within-group effect.

Recommendation: Join the acapella as adjunctive therapy with nursing practice care and rehabilitation of dyspnea for patients after coronary artery bypass grafting Surgery and conduct a clinical study to examine acapella with deep breathing and cough trials in patients who will undergo coronary artery bypass grafting surgery with lung problems such as chronic obstructive pulmonary disease and asthma.

List of Abbreviations

ABG, arterial blood gas; BMI, body mass index; CABG, coronary artery bypass grafting; CI, confidence interval; IS, incentive spirometry; PPC, postoperative pulmonary complication; RCT, randomized controlled trial; SD, standard deviation; SPSS, Statistical Package for the Social Sciences.

INTRODUCTION

Coronary artery disease (CAD) is a significant contributor to morbidity and mortality globally (2) Postoperative pulmonary complications (PPCs) are strongly associated with increased mortality and higher health care costs after surgical procedures (3) Postoperative pulmonary complications (PPCs) which refer to any pulmonary abnormality that arises during the postoperative period, manifesting as identifiable, clinically significant diseases or disorders that adversely affect the clinical trajectory. (4) postoperative complications of Coronary Artery Bypass Graft (CABG) may have reduced functional performance, muscle strength, and pulmonary function reduce in Arterial Blood Gas (ABGs) such as (pH, PaO₂, PaCO₂, and HCO₃⁻) at hospital discharge (5) various chest physiotherapy and respiratory exercises, with or without the use of mechanical devices. Various methods can be employed to enhance respiratory health and functionality. These encompass posture, incentive spirometry (IS), early mobilization, expiratory positive airway pressure, respiratory muscle training, cough assistance, deep breathing exercises, and the active cycle of breathing technique (ACBT) (6). the application of incentive spirometers (triflo), positive expiratory pressure (PEP) devices, and vibration devices (acapella) within the domain of physiotherapy (7). In the postoperative phase of CABG, respiratory physiotherapy has been suggested to advance lung functioning and prevent or treat pneumonic problems. As of right now, incentive spirometry (IS) is being used to predict PPC. Prior studies have evaluated the effects of various respiratory physiotherapy interventions on PPC following CABG, including breathing and coughing exercises, incentive spirometry, and expiratory positive airway pressure (EPAP) (6). Incentive spirometer (IS) is the mainstay of care in postoperative and hospitalized patients that has been heavily studied in the inpatient setting (8). It encourages the patient to perform slow and deep inspiration through visual feedback, allowing for the stretching and opening of collapsed airways. Incentive spirometer exercise is useful as it is inexpensive, simple to use, with no known side effects, and does not require supervision once the patient is trained in its use (9).

Whereas, Acapella comprises an anti-weight cover and a metal bar linked to a handle and magnet. The airflow oscillation is produced by the disruption and restoration of magnetic gravity via the plug, which periodically interrupts the air flow through the unit (10). Although both devices are widely used in clinical practice, previous studies have reported inconsistent findings regarding their effectiveness on respiratory outcomes after CABG surgery. A study by Jage, B, etal, suggest that the addition of Acapella enhanced the effect conventional physiotherapy in improving lung volumes and airway clearance in the early post-operative period for CABG patients (11).

Another study found Incentive spirometry after coronary artery bypass graft surgery improves oxygen levels and vital signs (12). No singular strategy is favored for enhancing pulmonary function (13). In numerous studies, intense spirometry and acapella have been extensively utilized, particularly in the postoperative care of heart surgery patients to enhance gas exchange and oxygenation (14). However, the outcomes exhibit significant variability. Therefore, further randomized controlled trials are essential to determine the most effective postoperative respiratory intervention for improving pulmonary outcomes among CABG patients.

Composed paper examining the efficacy of Acapella as an instrument for facilitating secretion clearance in diverse pulmonary disorders (15). The literature review indicates that the research by Williams, et al. found that Oscillation and pulmonary expansion (OPE) therapy did not produce any known adverse effects, especially concerning new or altered state pneumothorax, in patients with elevated American Society of Anesthesiologists (ASA) scores who are more vulnerable to postoperative complications. Randomized controlled prospective trials are necessary to give more solid data to support our conclusions. Moreover, further research is required to assess the application of OPE therapy among diverse postoperative patient cohorts (16).

This study aimed to investigate the effect of acapella and incentive spirometry on Partial Pressure of Carbon Dioxide in patients after coronary artery bypass grafting surgery.

MATERIALS AND METHODS

Study design and registration

This was a randomized, controlled, single-blind, parallel-group, three-arm trial with a 1:1:1 allocation. The trial was prospectively registered at ClinicalTrials.gov (NCT07337746) before the commencement of participant recruitment. The study received approval from the Research Ethics Committee (Approval No. 37) on 25 March 2025. Participant recruitment began after trial registration and ethics approval. The study was conducted in accordance with the Declaration of Helsinki and is reported in accordance with the CONSORT 2010 Statement (see Figure 1).

Participants and eligibility

The study enrolled adults admitted for coronary artery bypass graft (CABG) surgery at two cardiac surgery centers in Baghdad, Iraq: The Iraqi Center for Heart Diseases (Baghdad Health Directorate) and the Ibn al-Bitar Specialized Cardiac Surgery Center (Al-Karkh Health Directorate). Participant recruitment was conducted between 8th December 2025 and 1 April 2026.

Inclusion criteria were: age 33–75 years; body mass index >16 kg/m²; receipt of the same anesthetic protocol; fluency in Arabic; and ability to understand the study procedures. Exclusion criteria were: a diagnosis of asthma or chronic obstructive pulmonary disease; need for tracheal re-intubation; a history of respiratory disease; chronic smoking; recent cardiac surgery; cardiac arrhythmia; a history of cerebral aneurysm; inability to follow the study protocol; and insufficient cognitive ability to use the Acapella device or perform the breathing measurements correctly. Written informed consent was obtained from every participant at each center before enrolment.

Randomization, allocation concealment and blinding

Participants were randomly allocated in a 1:1:1 ratio to the control, incentive-spirometry, or Acapella group using a computer-generated randomization sequence created with IBM SPSS Statistics version 27 (IBM Corp., Armonk, NY, USA) using the random number generator. Permuted block randomization with a fixed block size of six was used to ensure balanced allocation across the three study groups.

Allocation concealment was achieved using sequentially numbered, opaque, sealed envelopes (SNOSE) prepared by a research assistant who was not involved in participant recruitment, intervention delivery, or outcome assessment. The envelopes were opened sequentially only after a participant had provided written informed consent and completed the baseline assessment.

The randomization sequence was generated by an independent statistician who was not involved in participant recruitment, intervention delivery, outcome assessment, or data analysis. Participants were enrolled by the principal investigator, who assigned them to their allocated intervention according to the concealed randomization sequence.

The trial was single-blind. The outcome assessor who measured Partial Pressure of Carbon Dioxide at all assessment time points and the statistician who performed the data analysis were blinded to group allocation. because of the nature of the interventions, participants and the physiotherapists delivering the interventions could not be blinded.

Interventions

Participants in the study groups received individualized instruction one day before surgery. In the incentive-spirometry group, patients sat upright, held the device vertically, sealed their lips around the mouthpiece and performed a slow, deep, sustained inspiration; the exercise was repeated 10–15 times per set, twice daily, on (10 hours after extubation, day one after extubation,

and day three after extubation) after weaning from mechanical ventilation. Failure to reach the 1200 mL target volume was not counted as treatment failure, to avoid selection bias.

In the Acapella group, patients sat comfortably, leaned forward with the elbows supported and the neck slightly extended. The device was held roughly horizontal and tilted to optimize vibration. Patients inhaled slowly and deeply, held the breath for 3–5 seconds, then exhaled slightly faster through the device; after 5–9 breaths a deep inspiration was followed by a forced expiration through the device to trigger a controlled cough. Each session comprised 10–15 breaths, twice daily, on (10 hours after extubation, day one after extubation, and day three after extubation) with short pauses to avoid hyperventilation.

The control group received usual postoperative care, which consisted of standard chest physiotherapy, early mobilization, positioning, routine postoperative analgesia, oxygen therapy as clinically indicated, and encouragement to perform coughing and deep-breathing exercises in accordance with the institutional postoperative CABG protocol. The same usual-care protocol was implemented at both participating cardiac surgery centers to ensure consistency throughout the study. To improve reproducibility, the key parameters of each intervention are summarized in Table 1.

Table 1. Standardized intervention protocol for each study arm.

Parameter	Incentive Spirometry Group	Acapella Group	Control Group (Usual Care)
Intervention	Incentive spirometry	Acapella oscillatory positive expiratory pressure (OPEP) therapy	Standard postoperative care only
Device / model	Voldyne® 5000 Volumetric Incentive Spirometer (Teleflex Medical, USA)	Acapella® Choice (Green), Smiths Medical, USA	Not applicable
Patient position	Sitting upright	Sitting upright with slight forward lean and elbows supported	According to routine postoperative care
Technique	Slow maximal inspiration followed by a 3–5-second inspiratory hold and relaxed exhalation	Slow deep inspiration, 3–5-second inspiratory hold, followed by active exhalation through the Acapella device	Standard postoperative care without incentive spirometry or Acapella therapy
Repetitions per set	10–15 breaths	10–15 breaths	Not applicable
Frequency	Two sessions daily	Two sessions daily	Routine postoperative care
Intervention period	two session every day, on 10 hours after extubation and continued for 3 days following extubation	two session every day, on 10 hours after extubation and continued for 3 days following extubation	Throughout the postoperative hospital stay
Session duration	10–15 minutes	10–15 minutes	According to routine care
Device setting	Target inspiratory volume individually adjusted according to patient tolerance, aiming for approximately 1,000–1,500 mL	Medium resistance (Dial Setting 3), adjusted according to patient tolerance to achieve effective oscillation during expiration	Not applicable
Supervision	Supervised by a trained physiotherapist during hospital sessions.	Supervised by a trained physiotherapist during hospital sessions.	Routine postoperative care delivered by ward nursing and physiotherapy staff
Adherence monitoring	Treatment log completed after each session	Treatment log completed after each session	Not applicable
Co-interventions	Identical standard postoperative care, including analgesia, early mobilization, oxygen therapy as required, coughing exercises, and routine nursing care	Identical standard postoperative care, including analgesia, early mobilization, oxygen therapy as required, coughing exercises, and routine nursing care	Standard postoperative care, including analgesia, early mobilization, oxygen therapy as required, coughing exercises, and routine nursing care

Outcome measures

The measurements of PaCO₂ were extracted from the patients' clinical records (ABGs). Patients were instructed on how to use incentive spirometry and the Acapella device, depending on their group. 10 hours after extubation, when the patient's condition had stabilized, PaCO₂ was assessed. These measurements were then repeated on the first day after extubation and third day after extubation. to obtain a postoperative PaCO₂ value. To perform arterial blood gas (ABG) analyses, the ABL800 FLEX plus, manufactured by Radiometer of Denmark, was utilized in both the Iraqi Center of Heart Disease and Ibn-al Bittar Cardiac Center. This was conducted to collect demographic and clinical data from all patients at baseline, at the first follow-up visit, and at the second follow-up visit. Information on age, sex, level of education, marital status, occupation, then place of residence was collected using a demographic questionnaire.

Sample size

The sample size was determined a priori using G*Power version 3.1.9.7 (Heinrich Heine University, Düsseldorf, Germany) based on the primary outcome of Partial Pressure of Carbon Dioxide. A one-way analysis of variance (ANOVA) for comparison of three independent groups was assumed. Based on a medium effect size (Cohen's $f = 0.35$) reported in previous studies evaluating postoperative respiratory rehabilitation following coronary artery bypass graft surgery, a two-sided significance level of 0.05 and a statistical power of 80% were specified. The required minimum sample size was 84 participants (28 per group). To allow for potential withdrawals or incomplete follow-up, the recruitment target was set slightly above this minimum, and 85 participants were ultimately recruited and completed the study, satisfying the required sample size and providing the prespecified statistical power for the primary outcome.

Statistical analysis

All analyses were performed with IBM SPSS Statistics version 27.0. Categorical variables are summarized as frequencies and percentages, and continuous variables as mean $\pm$ standard deviation. The distribution of PaCO₂ values was examined with the Kolmogorov–Smirnov and Shapiro–Wilk tests. A chi-square (symbolized as χ^2) test of independence is a nonparametric hypothesis test was utilized to ascertain substantial differences across study groups about variables. Within-group change in PaCO₂ across three time points was evaluated with the Friedman test, and the effect size was expressed as Kendall's W (interpreted as small ≥ 0.1 , moderate ≥ 0.3 , and large ≥ 0.5 , with values approaching 1.0 indicating a very strong, near-perfect concordance). Between-group differences in postoperative PaCO₂ were analyzed using Kruskal–Wallis H test. $p < 0.05$ was considered statistically significant.

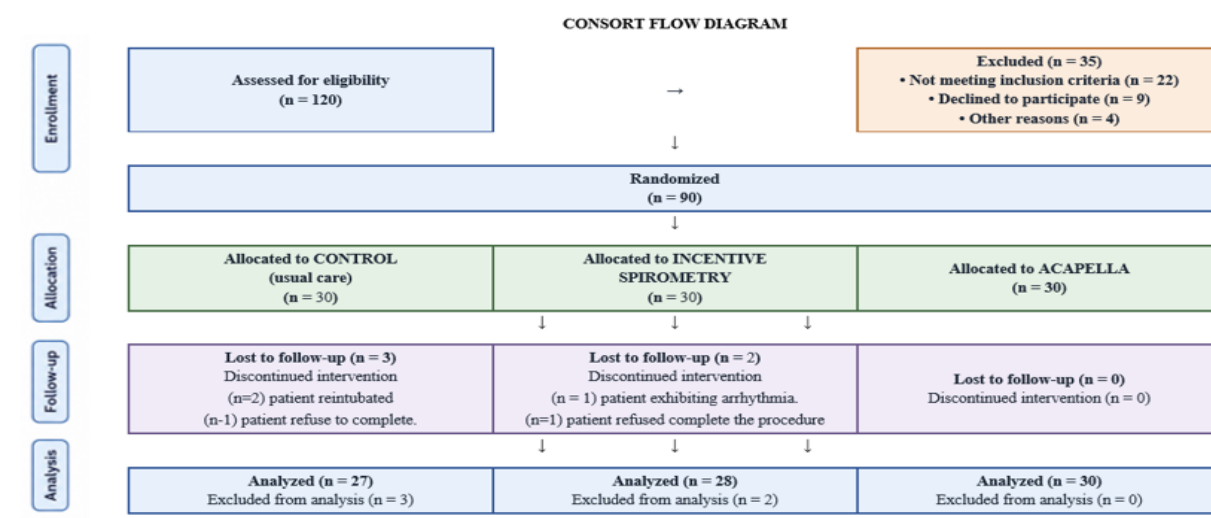


Figure 1. CONSORT participant flow diagram.

RESULTS

Participant flow and characteristics

A total of 120 patients scheduled to undergo coronary artery bypass graft (CABG) surgery were assessed for eligibility. Of these, 35 were excluded, including 22 who did not meet the inclusion criteria, 9 who declined to participate, and 4 for other reasons. The remaining 90 eligible patients provided written informed consent and were randomly allocated to the control group (n = 30), the incentive-spirometry group (n = 30), or the Acapella group (n = 30) and then (n=5) participants were lost to follow-up, discontinued the intervention, or were excluded from the final analysis. Consequently, 85 randomized participants completed the study and were included in the primary analysis (Figure 1).

Results

A total of 85 patients with coronary artery bypass grafting and initial assessment were randomly allotted to a control group (n = 27), the incentive spirometry group (n=28), and acapella group (n=30). All members given written informed consent. displays the descriptive comparison of clinical variables distributed in each group; the findings indicate that there are no significant differences in all clinical variables between study groups except the variable of stay duration in ICU that reported significant difference at p-value= .000.

The ejection fraction indicates a preserved (≥ 50) among the majority of patients in all group; control (92.6%), Incentive Spirometer (92.9%), and Acapella (96.7%). The duration of surgery refers to 5 – 6 hours among 66.7% in control group, 57.1% in the Incentive Spirometer, and 70% in Acapella group. The cardiac pulmonary bypass refers to less than 180 minutes among patients in all groups; control (59.3%), Incentive Spirometer (60.7%), and Acapella (56.7%). Concerning artificial ventilator hours, the patients in the control group (74.1%) and in the Spirometer group (57.1%) has prolonged ventilation for more than eight hours while 53.3% of patients in Acapella group had short ventilation. The duration of stay in ICU refers to three days for patients in the control group (77.8%), two days for patients in Spirometer group (82.2%), and one day for patients in the Acapella group (53.4%). **Table 1**

Table (1): Description of Patients' Clinical Variables in each Group.

List	Variables	Group	Control (n=27)		Incentive Spirometer (n=28)		Acapella (n=30)		Comparison Significance	
			No	%	No	%	No	%	χ^2	P
1	Ejection Fraction (EF)	Reduced (< 40)	1	3.7	0	0	0	0	2.711	.607
		Mildly reduced (40-49)	1	3.7	2	7.1	1	3.3		
		Preserved (≥ 50)	25	92.6	26	92.9	29	96.7		
2	Duration of surgery	5 – 6 hours	18	66.7	16	57.1	21	70	1.115	.573
		≥ 7 hours	9	33.3	12	42.9	9	30		
3	Cardio pulmonary bypass time/minute	< 180	16	59.3	17	60.7	17	56.7	.101	.951
		≥ 180	11	40.7	11	39.3	13	43.3		
4	Artificial ventilator/hours	Short ventilation (≤ 8)	7	25.9	12	42.9	16	53.3	4.456	.108

		Prolonged (> 8)	20	74.1	16	57.1	14	46.7		
5	Duration of stay in I.C. U	1 day	0	0	3	10.7	16	53.4	65.419	.000
		2 days	6	22.8	23	82.2	13	43.3		
		3 days	21	77.8	2	7.1	1	3.3		

No: Number; %: Percentage; χ^2 = Chi-square; P: Probability value.

Considering the sample size, the Kolmogorov-Smirnov and Shapiro-Wilk tests showed that all variables had significant p-values of $p < 0.05$, demonstrating refusal of the null hypothesis of normal distribution and concluding that the data for all variables are not normally distributed.

According distribution of PaCO₂ levels among patients in the study groups; the findings reveal at 10 hours after extubation immediately that normal levels were observed in 66.7% of the control group with mean of 42.78 ± 4.359 , 75% of Spirometer group with a mean of 43.60 ± 2.614 , and 83.3% of the Acapella group with a mean of 41.90 ± 3.207 . The Acapella group demonstrated the highest percentage of normal PaCO₂ levels. On Day 1 after extubation, Normal levels increased to 89.3% in the Spirometer with mean of 42.17 ± 2.640 , and 93.3% in the Acapella with mean of 40.66 ± 2.919 . Both groups showed better improvement in PaCO₂ level compared to control group. On Day 3, Normal levels further improved to 96.4% in the Spirometer with mean of 40.35 ± 2.280 , and 93.3% in the Acapella with mean of 38.60 ± 2.876 , and also to 85.2% in the control group with a mean of 40.67 ± 4.220 . **Table 2.**

Table (2): Descriptive Statistics for Partial Pressure of Arterial Carbon Dioxide Levels after Extubation following Coronary Artery Bypass Graft Surgery among Study and Control Groups.

PaCO ₂ Groups		Immediate After Extubation			Day 1 After Extubation			Day 3 After Extubation		
		No	%	M $\pm$ SD	No	%	M $\pm$ SD	No	%	M $\pm$ SD
Control (n=27)	Normal	18	66.7	42.78 ± 4.359	17	63	41.18 ± 5.460	23	85.2	40.67 ± 4.220
	Abnormal	9	33.3		10	37		4	14.8	
Incentive Spirometer (n=28)	Normal	21	75	43.60 ± 2.614	25	89.3	42.17 ± 2.640	27	96.4	40.35 ± 2.280
	Abnormal	7	25		3	10.7		1	3.6	
Acapella (n=30)	Normal	25	83.3	41.90 ± 3.207	28	93.3	40.66 ± 2.919	28	93.3	38.60 ± 2.876
	Abnormal	5	16.7		2	6.7		2	6.7	

No: Number; %: Percentage; M: Mean of total score; SD: Standard deviation,

Normal PaCO₂= 35 – 45 mmHg.

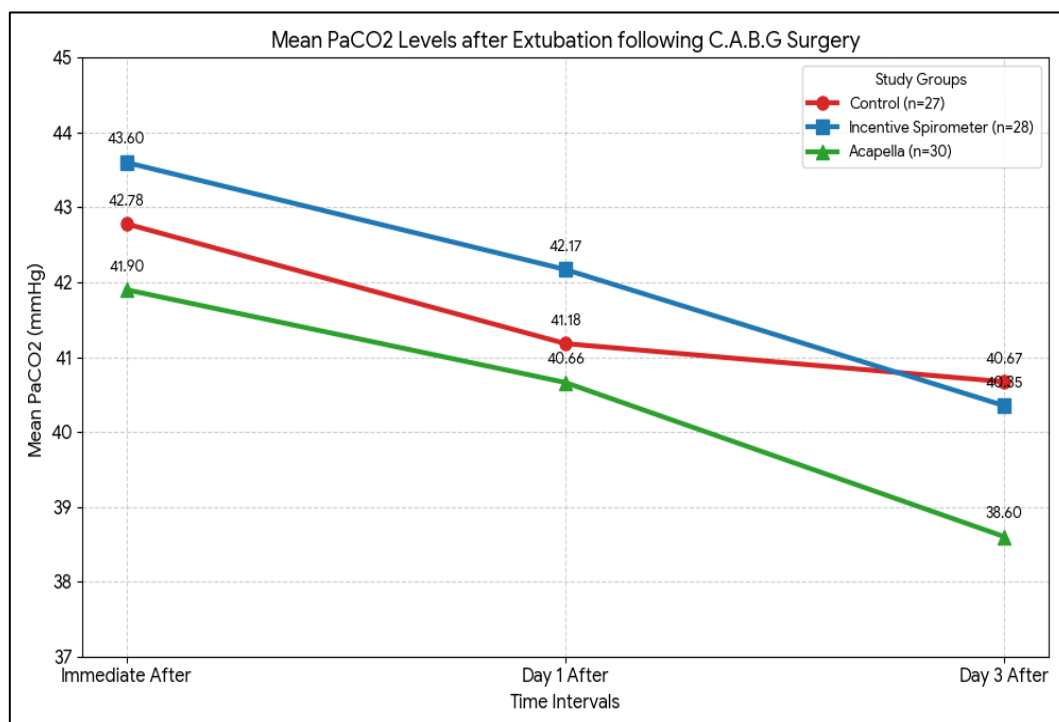


Figure 1: Partial Pressure of Arterial Carbon Dioxide Levels after Extubation following Coronary Artery Bypass Graft Surgery among Study Groups.

figure1: illustrates the progression of mean PaCO₂ levels across three-time intervals for the Control, Incentive Spirometer, and Acapella groups. All three groups showed a decrease in mean score levels from immediate post extubation to Day 3 indicating an improvement in ventilation and carbon monoxide over time.

There is statistically significant improvement in arterial carbon dioxide (PaCO₂) levels among all study groups following extubation after C.A.B.G surgery. The findings demonstrate significant reduction in PaCO₂ levels over the three measurement periods in the control group ($\chi^2 = 15.630$, $p = 0.000$) with moderate effect size (0.289); Incentive Spirometer group ($\chi^2 = 19.513$, $p = 0.000$) with moderate effect size (0.325); and Acapella group ($\chi^2 = 27.214$, $p = 0.000$) with large effect size (0.486). The high significant p-value and effect size indicate progressive improvement in post-operative ventilation and carbon dioxide elimination among study groups. However, the large effect size was observed in acapella suggesting highly effective in reducing carbon dioxide and enhancing pulmonary ventilation compared with routine care. **Table 3**

Table 3: Significant Differences in Partial Pressure of Arterial Carbon Dioxide Levels after Extubation following Surgery within Study Groups.

PaCO ₂ Groups	Times Points	Descriptive Statistics				Friedman Test				
		M	SD	Min	Max	Mean Rank	χ^2	df	p-value	Effect size*
Control (n=27)	Immediate After Extubation	42.678	4.3593	34.9	51.9	2.52	15.630	2	.000 H. S	.289
	Day 1 After Extubation	41.181	5.4608	26.7	49.4	2.04				
	Day 3 After Extubation	40.678	4.2208	29.5	47.0	1.44				

Incentive Spirometer (n=28)	Immediate After Extubation	43.604	2.6140	39.4	51.9	2.68	19.513	2	.000 H. S	.325
	Day 1 After Extubation	42.171	2.6403	35.8	47.8	2.04				
	Day 3 After Extubation	40.357	2.2809	34.9	43.8	1.29				
Acapella (n=30)	Immediate After Extubation	41.903	3.2072	31.5	45.9	2.40	27.214	2	.000 H. S	.486
	Day 1 After Extubation	40.660	2.9189	32.6	46.2	2.25				
	Day 3 After Extubation	38.607	2.8762	34.2	44.0	1.35				

M: Mean of total score, SD: Standard deviation, Min: Minimum, max: maximum, χ^2 : Chi-square, df: Degree of Freedom, P: probability, * Kendall's W.

According to differences between the three group, no statistical differences were found immediately after extubation (H= 2.734, p= 0.255) and on day 1 (H= 3.746, p= 0.154), but a significant difference was seen on day 3 (H= 8.797, p= 0.012) with regard to Acapella group that demonstrated the lower mean ranks indicating better reduction carbon dioxide levels. **Table 4.**

Table 4: Significant Difference in Effect on Arterial Carbon Dioxide Levels among Study Groups.

Groups		N	Immediate After Extubation				Day 1 After Extubation				Day 3 After Extubation			
			Me an Ran k	Krusk al-Wallis H	d f	P- val ue	Me an Ran k	Krusk al-Wallis H	d f	P- val ue	Me an Ran k	Krusk al-Wallis H	d f	P- val ue
PaC O ₂	Control (None)	27	45.24	2.734	2	.255	46.04	3.746	2	.154	51.44	8.797	2	.012
	Incentive Spirometer	28	47.16				47.54				45.91			
	Acapella	30	37.10				36.03				32.68			

N: Number; df: Degree of freedom; P: Probability.

DISCUSSION

This study aimed to investigate the effect of acapella and incentive spirometry on Partial Pressure of Carbon Dioxide rate. the results indicated that both acapella and incentive spirometry were significantly higher in immediately after the intervention and on day three after CABG surgery.

The first section of the data analysis finding showed the sample distribution of Patients' Clinical Variables in each Group, which reveal that the ejection fraction indicates a preserved (≥ 50) among the majority of patients in all group; control (92.6%), Incentive Spirometer (92.9%), and Acapella (96.7%). which is agree with a study conducted in Pakistan aimed to evaluate the impact of ejection fraction on outcomes after cardiac surgery, where the majority of the study sample had an ejection fraction

within the normal levels (17). On other hand the duration of surgery refers to 5 – 6 hours among 66.7% in control group, 57.1% in the Incentive Spirometer, and 70% in Acapella group. unlike a study conducted in Japan by Matsuura et al., where 109 patients out of 149 had an operative time of 480.90 ± 161.20 , which exceeded the operative time in the present study. (18). In this study the cardiac pulmonary bypass refers to less than 180 minutes among patients in all groups; control (59.3%), Incentive Spirometer (60.7%), and Acapella (56.7%). this result agrees with Madhavan et al. who found that Prolonged cardiopulmonary bypass (CPB) times may be able to predict postoperative clinical outcomes, most notably mortality. It is proposed that both the CPB/graft duration and the cumulative CPB time be kept below 56 minutes and 180 minutes, respectively, in order to reduce the likelihood of adverse outcomes occurring during the surgery. (19). Concerning artificial ventilator hours, the patients in the control group (74.1%) and in the Spirometer group (57.1%) has prolonged ventilation for more than eight hours while 53.3% of patients in Acapella group had short ventilation. This result agrees with Yazdannik A et al, in their study “The effect of incentive spirometry on arterial blood gases after coronary artery bypass surgery (CABG)” shows that mechanical ventilation Mean $\pm$ SD (9.2 ± 2) in the intervention group and Mean $\pm$ SD (8 ± 1.7) in the control group. (20). The duration of stay in ICU refers to three days for patients in the control group (77.8%), two days for patients in Spirometer group (82.2%), and one day for patients in the Acapella group (53.4%). **Table 1**

According to PaCO₂ Levels on Day 3, Normal levels further improved to 96.4% in the Spirometer with mean of (40.35 ± 2.280), and 93.3% in the Acapella with mean of (38.60 ± 2.876), and also to 85.2% in the control group with a mean of (40.67 ± 4.220). All three groups showed a decrease in mean score levels from immediate post extubation to Day 3 indicating an improvement in ventilation and carbon monoxide over time. **Table 2, figure 1.** This result agrees with Gökçe et al, in their study “Outcomes of Incentive Spirometry for Patients Undergoing Coronary Artery Bypass Surgery: A Randomized Controlled Trial”. reveal mean of (36.06 ± 3.07) in the experimental group and (36.95 ± 4.39) in the control group. (21).

In PaCO₂ Levels The high significant p-value and effect size indicate progressive improvement in post-operative ventilation and carbon dioxide elimination among study groups. the large effect size was observed in acapella group suggesting highly effective in reducing carbon dioxide and enhancing pulmonary ventilation compared with routine care. **Table 3.** This result agrees with El-Refaey et al, in their study reveal that There was significant improvement in arterial blood gases including a significant decrease in PaCO₂ and Hco₃, ($P < 0.05$) for three groups. Significant difference was noted between three groups postoperatively, in favor of incentive spirometer group.

Regarding PaCO₂, significant difference was seen on day 3 ($H = 8.797$, $p = 0.012$) with regard to Acapella group that demonstrated the lower mean ranks indicating better reduction carbon dioxide levels. **Table 4.** This result agrees with Alam et al, they reveal that both Acapella and incentive spirometry treatment after coronary artery bypass graft improved blood gases. The acapella shows better improvement than incentive spirometry in PaCO₂, PaO₂. (23).

CONCLUSION

The results of our study reveal that Acapella breathing exercises have a positive effect on Partial Pressure of Carbon Dioxide after coronary artery bypass graft (CABG) surgery. The study reveals a significant difference in pre- and postoperative Partial Pressure of Carbon Dioxide values between patients who performed Acapella breathing exercises and those who received spirometry and traditional chest physiotherapy after CABG. Active patient participation in Acapella breathing exercises is effective and can be used as a preoperative intervention in patients undergoing cardiac surgery.

Authors' Contribution

B.A and A.H. conceptualized the study, settled the methodology, reanalyzed the clinical and statistical data, and reviewed the manuscript. B.A collected clinical data, wrote the manuscript, and subsequently analyzed and explained the data. Both authors read and agreed the final form of the manuscript.

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