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STUDY TO FIND OUT THE EFFECT OF RESPIRATORY MUSCLE STRETCH GYMNASTICS ON PULMONARY FUNCTION IN A POST-OPERATIVE CORONARY ARTERY BYPASS GRAFTING – AN INTERVENTIONAL STUDY

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ABSTRACT

Background: Cardiovascular diseases (CVDs) continue to be a predominant global health issue, with atherosclerosis as a pivotal factor. Atherosclerosis is defined as the accumulation of lipid plaques in artery walls, resulting in constriction, rigidity, and potential obstructions that increase the risk of myocardial infarctions and cerebrovascular accidents. In severe cases, cardiovascular diseases may require surgical procedures such as coronary artery bypass grafting (CABG). Post-operative rehabilitation is crucial, especially for patients recovering after CABG, to improve results and avert problems.

In this study, the use of respiratory muscle stretch gymnastics (RMSG) into rehabilitation programs following CABG is investigated. The findings demonstrate that RMSG can significantly improve lung function, reduce surgical complications, and hasten the healing process. To confirm these benefits and evaluate their long-term impacts, more research is needed with larger, more diverse patient groups and longer follow-up periods.

Methodology: A total of 54 postoperative coronary artery bypass grafting patients were included in the study. Patients were randomly allocated to 2 groups: the experimental group (Group A) and the control group (Group B). Group A received conventional exercise-based cardiac rehabilitation and RMSG exercise, 4 sets, 3 days/week for 4 weeks. Group B received conventional exercise-based cardiac rehabilitation for the same period. After 4 weeks of exercise, assessment, and documentation of pulmonary function tests (FVC, FEV1, PEFR, PImax) and chest expansion.

Results: The results showed that there was statistically significant improvement in pulmonary function (FVC, FEV1, PEFR, PIMAX) and chest expansion in the experimental group (Group A) and the control group (Group B) after 4 weeks of intervention for all the outcome measures within the group. Between-group analysis showed more improvement in the experimental group (Group A) compared to the control group (Group B) on all outcome measures.

Conclusion: The study concluded that respiratory muscle stretch gymnastics improve pulmonary functions (FVC, FEV1, PEFR, PImax) and chest expansion in patients with coronary artery bypass grafting.

Keywords: pulmonary function, respiratory muscle stretch gymnastics, chest expansion, coronary artery bypass grafting

INTRODUCTION:

Globally, coronary artery disease (CAD) continues to be the leading cause of illness and mortality. The World Health Organization (WHO) has continuously highlighted the rising prevalence of cardiovascular diseases for over ten years. According to population-based research, the prevalence of CAD has roughly quadrupled over the past four decades, affecting roughly 10% of adults today (1,2). The standard surgical treatment for CAD, which is primarily caused by atherosclerotic stenosis of the coronary arteries and is particularly prevalent in the elderly population, is coronary artery bypass grafting (CABG) (3). The number of CABG procedures performed in India has increased significantly. Indian patients often have double or triple vessel involvement and are operated on at a slightly younger age (around 60 years) (4).

Although significant progress has been made in surgical practice including the use of off-pump procedures, minimally invasive techniques, improved myocardial preservation strategies, expanded application of arterial grafts, and advancements in perioperative management—CABG continues to be associated with notable risks [(5)]. On the other hand, CABG still carries several risks. Lung infections, respiratory muscle weakness, and problems with lung function are common surgical consequences, mostly after sternotomy and cardiopulmonary bypass. other Additional issues include musculoskeletal problems, cognition problems, and surgical death (1–2%, depending on urgency and comorbidity). (6,7)

Respiratory dysfunction is one of the most common post-surgery complications.. Sternotomy pain often makes it hard to breathe deeply, move the chest wall, and use the diaphragm (8). Pain from the incision and limited movement of the shoulder girdle can also make it even harder for the rib cage to expand (9). Patients often express left-sided shoulder pain, which is likely linked to how they are positioned during surgery and the use of sternal retractors (10). Preservation of respiratory muscle activity is therefore crucial after CABG, both to lower the risk of pulmonary complications and to promote early functional recovery. Conventional postoperative strategies, such as analgesics and relaxation techniques, may offer symptomatic relief but are inadequate for restoring respiratory muscle performance. This highlights the need for active rehabilitation interventions(11)

Cardiac rehabilitation (CR) is a wide-ranging program that involves many different types of health professionals and helps people recover from heart surgery and stay healthy. There are three primary parts to the execution of CR: period I, which is the first inpatient period; Phase II, which is an early outpatient phase that focuses on teaching patients and having them do supervised exercise sessions; and Phase III, which is a maintenance phase that tries to keep the results over time. Research repeatedly shows that participating in CR lowers the risk of cardiac disease, lowers the number of hospital readmissions, improves functional ability, and improves quality of life overall (12). Physical therapy is an important part of cardiac rehabilitation since it speeds up healing after surgery. Muscle training for inhalation and exhalation, diaphragmatic breathing, pursed-lip breathing, and positive expiratory pressure (PEP) therapy are all examples of interventions that have been shown to enhance pulmonary mechanics, diaphragm function, and airway clearance (13–16).Additionally, lifestyle changes like quitting smoking, restricting one's diet, and managing stress provide additional benefits that improve surgical outcomes and support long-term cardiovascular health (17, 18).

Respiratory Muscle Stretch Gymnastics (RMSG) is a way to stretch and control your breathing to work on the muscles that help you breathe. RMSG is different from regular breathing exercises because it works on the flexibility, coordination, and functional ability of both the muscles that help you breathe in and the muscles that help you breathe out. The technique works by making the thorax less stiff, the costovertebral and sternocostal joints more flexible, and the chest wall expand more easily. All of these things help the lungs work better (19). People with long-term lung diseases have also said that RMSG has helped them, such as by increasing lung volumes, making it easier to clear their airways, and making it easier to breathe during everyday activities.

RMSG is already known to help those with chronic respiratory disorders, but early study suggests it may also help people who have just had heart surgery, where lung problems are common after surgery. After CABG, sternotomy pain, diaphragm dysfunction, and reduced chest wall flexibility can significantly impair lung function. Traditional rehabilitation often includes planned exercise and breathing exercises; however, these methods may not fully restore thoracic flexibility and respiratory muscle strength. In this case, RMSG may be beneficial because it tries to make breathing mechanics better.

Even though these benefits are possible, RMSG is still not widely used in cardiac rehabilitation after surgery, and there isn't enough strong evidence to show how it works for people who have had CABG. Consequently, this study has been conducted to examine the efficacy of RMSG as a postoperative intervention, aiming to assess its influence on chest wall mobility and pulmonary function in patients post-CABG.

METHODOLOGY

This interventional study was initiated following approval from the Institutional Ethics Committee. Participants were recruited from a tertiary cardiac care center using simple random sampling. A total of 86 patients who had undergone CABG and were in Phase II of the postoperative period (between 6 and 12 weeks) were screened. The required sample size was determined using RAO software, which indicated that a minimum of 56 participants was sufficient to achieve a statistical power of 0.90 at a 95% confidence interval.

Participants eligible for the study were men and women between 30 and 65 years of age who were at least six weeks post-CABG. Additional requirements included the presence of a stable sternum (SIS score 0–1), minimal pain levels (NPRS 0–1), and the ability to actively cooperate with the intervention. .Only non-smokers or those who had ceased smoking for a minimum of one year were considered, and individuals with managed comorbidities such as diabetes or hypertension (blood pressure maintained at ≤140/90 mmHg) were included. Exclusion criteria included a clinical diagnosis of osteoporosis, a SPADI score of 20 or above, any pre-existing pulmonary disease, postoperative wound infection, re-suturing or wound gapping, and severe reductions in lung function (FEV1 <30% of predicted, based on GOLD criteria). Patients with severe tachycardia, neurological or musculoskeletal conditions that could influence the study outcomes, or those unwilling to participate were also excluded.

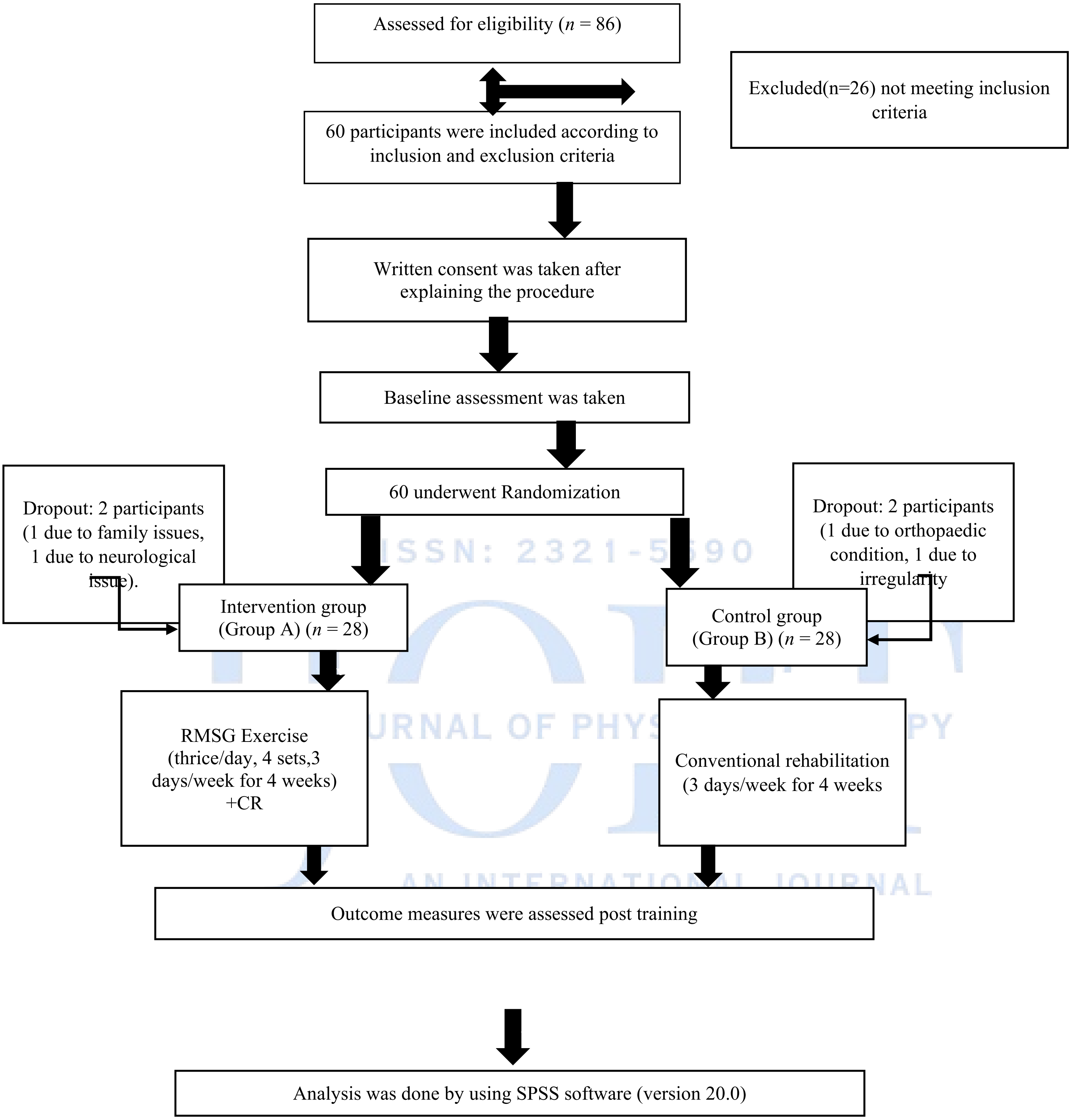
The intervention was terminated if a participant chose to withdraw, exhibited symptoms consistent with New York Heart Association (NYHA) Class II or higher, developed new neurological complications, or was unable to maintain regular attendance during the study period.

Procedure

After approval from the institutional ethics committee, individuals were assessed based on inclusion and exclusion criteria. A total of 60 participants who met the criteria for inclusion were randomly assigned to two groups: intervention (Group A) and control (Group B). Participants signed a consent form after informing about the study to indicate their willingness to participate. We recorded and measured each participant's peak expiratory flow rate (PEFR), forced expiratory volume in one second (FEV1), forced vital capacity (FVC), maximal inspiratory pressure (PImax), and chest expansion at the beginning and conclusion of the intervention to see how the training worked.

During a full screening session, sociodemographic information, comorbidities, medications, initial pain levels, and the sternal instability scale (SIS) were all collected. Also measured was tragus-to-wall distance. Each subject's weight was measured on a calibrated weighing scale (to the nearest 0.1 kg), and their height was measured with a stadiometer (to the nearest 0.01 m). The participant's BMI has been calculated (kg/m^2).

The study was randomized using a concealed allocation method [Flowchart 1]. Each person picked a folded piece of paper from a box that said either "IG" (Intervention Group) or "CG" (Control Group). The lead investigator assigned each participant to the correct group based on the slip they chose. This technique made guaranteed that each participant had the same chance of being put in either group, which lowered the chance of systematic bias. To ensure methodological integrity, an independent physiotherapist who was unaware of the study's objectives and protocols oversaw the allocation process. Furthermore, participants were not informed of their group assignment, resulting in a blind intervention phase.



Flowchart-1

Intervention

Group A (n = 28) was instructed to do the RMSG exercise thrice/day, 4 sets, 3 days/week for 4 weeks (9) with conventional rehabilitation. The RMSG exercises were performed in a standing position, whereas Group B (n = 28) was told to perform conventional rehabilitation (3 days/week for 4 weeks) (10). After the initial assessment, the subjects were taught the RMSG exercises and conventional rehabilitation by giving a brief description along with a demonstration of the exercises. Once a day, exercise was performed under supervision, and then the subjects were asked to perform these exercises on their own for the other two times. A record of the performance of the exercises for the other two times in a day was kept by means of telephonic intervention. The following four patterns of RMSG exercises were performed:

RMSG

Start with a relaxed position with a straight back. Slowly elevate both shoulders while moving them backward. At the same time, lean back while inhaling. After full inspiration, exhale slowly, relax, and resume the original position

↓

With the back straight, hold both hands at the back of the buttocks. After full and slow inspiration, push the hands away from the body while slowly exhaling. After full expiration, breathe quietly and resume the original position

↓

With the back straight, hold both hands in front of the chest with the fingers entwined and the palms fully in this position. Then extend the arms and bend the upper body as far forward as possible while exhaling slowly. After arm extension and body bending, take a full breath in that position. Then breathe quietly and resume the original position

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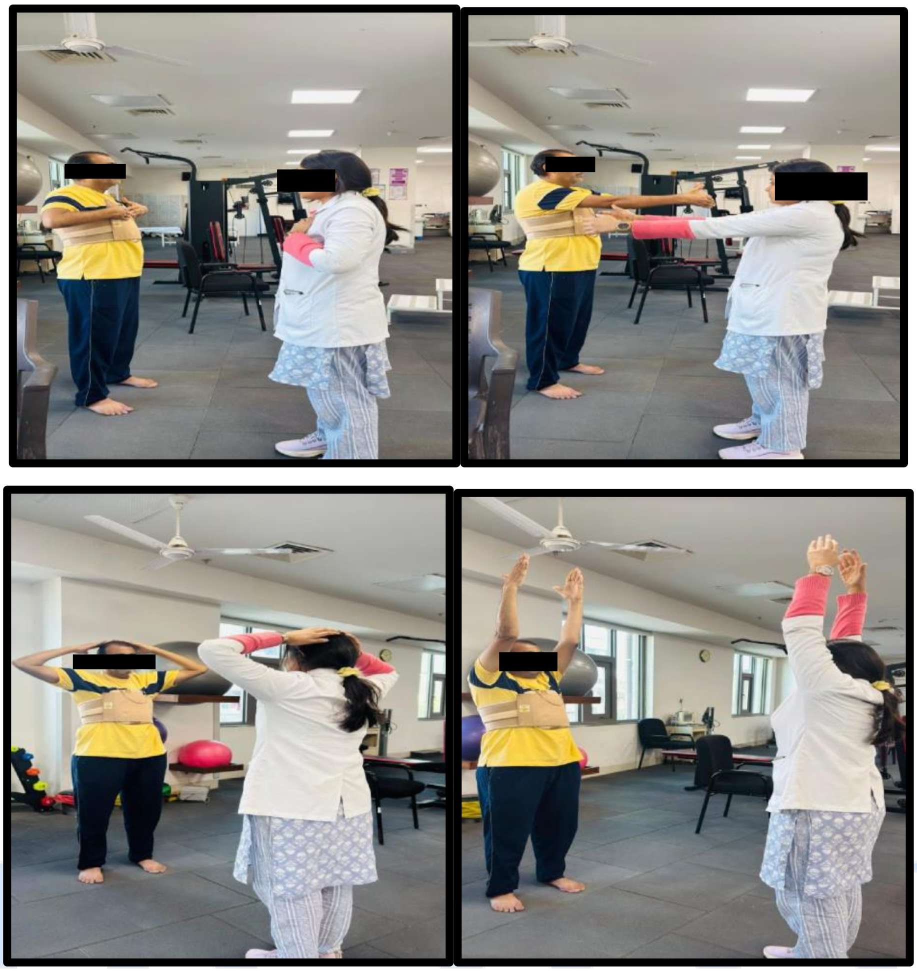
With the back straight, hold both hands above the head with arms stretched and palms facing each other. After full inspiration, in this position, pull the arms back while exhaling slowly. After full expiration, resume the original position and breathe quietly



Conventional Rehabilitation: Control group continued with their routine treatment, which included conventional CR for 4 weeks, for 3 alternate days of a week, along with the routine instruction and medical management**.** Exercise prescription for the control group is as follows:

CR PROGRAM	**Warm up**	**Aerobic training**	**Resistance training**	**Cool down**
Frequency	3 days/week	3 days/week	3 days/week	3 days/week
Intensity	RPE 9 – 13	RPE 12 to 16	RPE 11-13	To the point of slight discomfort or stretch
Repetition/ Time	1 set of 10 repetitions	20 minutes	(1- 3 sets of 10 – 15 reps)	15 seconds for 4 repetitions

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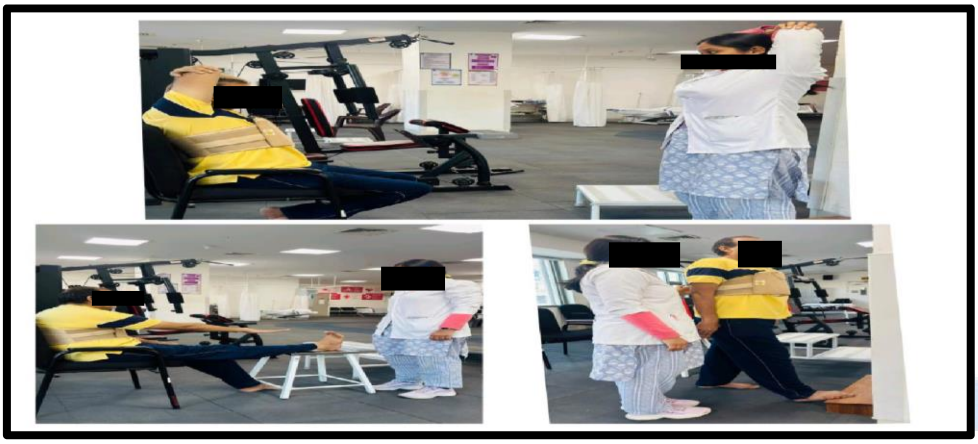
Type	Active ROM of the B/L upper and lower limbs and trunk	Static cycling, treadmill, arm ergometer	B/L shoulder abductors, elbow flexors, knee extensors, and knee Flexors	elbow and wrist flexors, elbow extensors, hamstrings, quadriceps, calf

Before and after the completion of the 4 weeks, the same outcome measurements were taken. After completion of the intervention, statistical analysis was done within and between groups to see the effect of the intervention.



OUTCOME

Assessment of FVC, FEV1, and PEFR

The FVC was assessed using a computerized LFX system and GANSHORN pulmonary function software, in accordance with the American Thoracic Society/European Respiratory Society (ATS/ERS) recommendations. Prior to testing, participants were sat comfortably in a chair and given 15 minutes to relax in a well-ventilated environment. They were advised not to drink coffee or tea and not to engage in any physical activity on the day of testing. They were also advised to remove the chest binder to allow full chest and abdominal expansion. Before the test started, the participant was given an explanation of the steps that will be taken. The subject's demographic information, such as name, age, height, and weight, was taken without shoes. The subject gets a briefing on the procedure so they know what to expect and agree to take the test. They should sit or stand up straight and apply a nose clip to make sure that breathing only happens via the mouth. They should maintain an upright posture, either seated, and a nose clip should be applied to ensure breathing occurs only through the mouth. The subject must tightly seal their lips around the spirometer mouthpiece and take a few normal breaths. They should then take a deep breath, filling their lungs, followed by a rapid and forceful exhalation, expelling as much air as possible within the first second, up to 6 seconds. This is followed by another deep and forceful inhalation. The process should be repeated until three good, consistent efforts are achieved, ensuring the subject maintains correct posture and effort throughout, and the best of the 3 trials was selected (11).

Assessment of maximum inspiratory pressure (PImax)

The PImax test was done according to ATS/ERS rules. The computerized LFX pulmonary function program was used for the procedure. Before the exam, the subject should be given information about the procedure so that they understand and are willing to take part. The individual must maintain an erect posture, whether seated or standing, and a nose clip should be utilized to enable exclusive oral respiration. The individual will put their lips tightly around the mouthpiece of the manometer or pressure gauge after they have fully exhaled. After that, they will be told to take the deepest and most forceful breath possible, which will put the most pressure on the device. the best of 3 trial was selected.the PImax was used to evaluates how strong your lungs' muscles are when you breathe in hard (12).

Assessment of chest expansion

The chest expansion was performed accordance with Pagare RS et al. The instrument used for the measurements was a measuring tape. To ensure accurate placement of the tape, subjects were asked to remove their clothing if they felt comfortable doing so. The tape has been placed on the chest at two different levels to assess chest expansion. For upper chest expansion, wrap the tape around the body at the level of the 5th thoracic vertebra in the back and align it with the 3rd intercostal space at the midclavicular line in the front. For lower chest expansion, the tape was situated at the level of the 10th thoracic vertebra in the back and aligned with the tip of the xiphoid process in the front, just below the breastbone. These anatomical reference points facilitated precise and consistent measurements of chest expansion during respiration, providing important information about respiratory function (13).

RESULT

All 58 individuals followed the study procedure exactly as anticipated. The Kolmogorov-Smirnov test was used to examine the distribution of data in both Group A and Group B. The Kolmogorov-Smirnov test was used to determine the normality of the data in groups A and B. For within-group comparisons, normally distributed data were analyzed with the paired t-test, while non-normally distributed data were analyzed with the Wilcoxon signed rank test.For between-group comparisons, the unpaired t-test was applied to normally distributed data, and the Mann–Whitney U test was employed for non-normally distributed data." Normality testing showed that BMI, FVC, PEFR, and PImax were normally distributed, while age and chest expansion were not. Baseline comparisons showed no significant differences between groups in demographics, pain, SIS, SPADI scores, comorbidities, age, BMI, hospital stay, or tragus-to-wall distance (all $p \geq 0.05$), which means that both groups were similar at the start.

Table 1: **Pre- and post-data comparison within the intervention group**

	FVC	FEV1	PEFR	PImax	Chest expansion		
PRE	1.98±0.92	1.6±0.5	3.65±1.83	2.46±1.56	1.18±0.39	1.25±0.44	1.21±0.42
POST	2.65±0.61	2.05±0.42	5.33±1.43	5.29±2.14	1.79±0.42	2.66±0.45	3.86±0.72
p-value	0.00⊖	0.00⊖	0.00⊖	0.00⊖	0.00⊖	0.00⊖	0.00⊖

Pre- and post-data analysis showed a significant difference ($P<0.05$) at the 95% confidence level for vital capacity, expiratory volume in 1 second, expiratory flow rate, and PImax (maximum inspiratory pressure).

Table 2: **Pre- and post-data comparison within the control group**

	FVC	FEV1	PEFR	PImax	Chest expansion		
PRE	2.13±0.51	1.69±0.41	3.18±1.07	2.66±1.03	0.96±0.13	1.5±0.58	1.39±0.5
POST	2.21±0.48	1.72±0.38	3.15±0.9	2.76±1.27	1.82±0.37	2±0.72	1.88±0.79
p-value	0.004⊖	0.328⊖	0.00⊖	0.33⊖	0.00⊖	0.00⊖	0.00⊖

Pre- and post-data analysis showed a significant difference ($P<0.05$) at the 95% confidence level for vital capacity, expiratory volume in 1 second, expiratory flow rate, and PImax (maximum inspiratory pressure).

Table 3: Postintervention comparison between intervention and control group

	Intervention group	**Control group**	**p-value**	**EC**
FVC	0.640±0.411	0.077±0.129	0.00⊖	1.84
FEV1	2.05±0.5	1.6±0.42	0.00⊖	0.9
PEFR	2.82±1.48	0.1±0.57	0.00⊖	2.41
PImax	2.02±0.90	0.27±0.745	0.00⊖	2.42
Chest expansion	0.85±0.56	0.6±0.299	0.11	0.57
	1.41±0.720	0.50±0.88	0.00⊖	1.19
	2.64±0.83	0.48±0.83	0.00⊖	2.6

PImax (maximum inspiratory pressure), expiratory volume in the 1st second, expiratory flow rate, and vital capacity all showed significant differences ($P<0.05$) at the 95% confidence level in the between-group comparison.

DISCUSSION

This study concluded that, in the intervention group, all the outcome measures were statistically significant. Group A (the interventional group) received RMSG and a conventional exercise protocol. The effect of respiratory muscle stretch gymnastics is attributed to relaxing the respiratory muscles, minimizing atrophy of the respiratory muscles and movement limitation, and improving the ventilatory and non-ventilatory functions of the respiratory muscles. Group B (the standard exercise protocol) is to improve exercise performance, vascular function, myocardial perfusion, lipid metabolism, glucose tolerance, and autonomic function. Both groups showed big improvements, both within and between groups. However, the interventional group show the greater improvement. There is limited evidence on the effects of respiratory muscle stretch gymnastics on pulmonary function following coronary artery bypass.

According to research by Elisabeth Westerdahl et al (14), patients who undergo cardiac surgery often do not fully recover pulmonary function, as measured by static and dynamic lung volumes, even one year after surgery. The reasons for the pulmonary impairment found one year postoperatively are unknown, but changes in chest wall mechanics, opening of the pleural space, cardiopulmonary bypass procedure, changes in blood cortisol and C-reactive protein concentrations, and postoperative phrenic nerve paralysis and associated diaphragmatic dysfunction could be reasons for impaired pulmonary function.

According to research by Ulfa Nur Rohmah et el (15), patients with COPD showed a decrease in pulmonary function. They found that the treatment group showed an increase in lung function and quality of life, while the control group did not. Possible mechanism shows that RMSG involves a regimen of stretching and strengthening exercises that target the respiratory muscles, including the diaphragm and intercostal muscles. By increasing muscle strength and endurance, RMSG enables patients to generate greater inspiratory pressures and improve airflow. This is supported by studies demonstrating significant increases in maximum inspiratory pressure (PImax) (P=0.00) following RMSG. In this study, the interventional group exhibited a notable improvement in PImax after 4 weeks of RMSG exercise. RMSG has been shown to reduce chest wall stiffness and enhance compliance. By relaxing the stiffened muscles, RMSG promotes greater chest wall expansion (at all three levels) and tidal volume, resulting in improvements in forced vital capacity (FVC) and peak expiratory flow rate (PEFR). Stiffened intercostal muscle spindles may lead to dyspnea and changes in breathing patterns.

Bima Aminul Karim et al. (16) suggested that reducing "out-of-phase" muscle spindle discharges may alleviate dyspnea and enhance respiratory mechanics, potentially leading to an increased forced expiratory volume in one second (FEV1) By improving lung function, RMSG can improve expiratory flow rates and airway dynamics.Supporting studies have shown that FEV1 improves a lot after RMSG. Increased expiratory flow rates make air expulsion easier, lowering airway blockage and increasing the volume of air released during the first second of forced expiration.In conclusion, RMSG provides a holistic approach to improve pulmonary function in COPD patients.

.It can reduce dyspnea, make exercise easier, and improve general quality of life by strengthening respiratory muscles and increasing chest wall flexibility. According to Akhtar SA et al. Post-operative CABG patients experience the restricted thoracic mobility and reduced lung function due to pain, sternal precautions, and respiratory muscle weakness. In our investigation, the intervention group that got RMSG in addition to conventional rehabilitation had a significant enhancement in chest expansion at all assessed levels as compared to the control group. This enhancement aligns with other research that emphasizes the significance of thoracic mobility exercises and respiratory muscle training in augmenting chest expansion (16).

The current study indicated that RMSG, when integrated with a standard exercise regimen, resulted in statistically significant enhancements in pulmonary function and chest expansion in patients post-CABG surgery. While both groups demonstrated improvement, but the interventional group shown superior benefits across all outcome measures, including PEFR, FEV_1, FVC, PImax, and chest expansion..

The greater effects of RMSG may be attributed to its ability to relax and stretch the respiratory muscles, reduce stiffness, and enhance both ventilatory and non-ventilatory functions. By targeting the diaphragm and intercostal muscles, RMSG improves muscle strength, endurance, and inspiratory pressure generation, which in turn enhances airflow. The intervention group's significant increase in PImax after four weeks of training demonstrates this improvement. Additionally, the greater increases in FVC and PEFR in this group likely resulted from improved chest wall compliance and mobility.

According to Westerdahl et al. (14), patients who undergo cardiac surgery often experience lasting impairments in both static and dynamic lung volumes, even one year after the procedure. Possible explanations for these impairments include altered chest wall mechanics, pleural opening, the effects of cardiopulmonary bypass, inflammatory changes, or dysfunction of the diaphragm. Akhtar et al. have noted an improvement in thoracic mobility and respiratory muscle weakness often seen CABG, aligning with the preliminary findings in our cohort study.

The evidence from non-cardiac populations further supports these findings. Rohmah et al. (15) find that RMSG enhanced lung function and quality of life in patients with COPD. Karim et al. (16) posited that RMSG diminishes “out-of-phase” discharges from intercostal muscle spindles, facilitating alleviation from dyspnea and enhancing respiratory mechanics. Normalizing muscle spindle activity leads to improved expiratory dynamics, which explains the observed improvements in FEV_1 and peck expiratory flow rates in this study

The results show that RMSG has many benefits in the post-CABG setting. RMSG may help with recovery, lower the risk of lung problems, and improve overall exercise tolerance by making the respiratory muscles work better, making the chest wall less stiff, improving compliance, and optimizing airway dynamics.

CONCLUSION

The clinical advantages of incorporating RMSG into standard cardiac rehabilitation following CABG are emphasized in this study. The method yielded greater improvements in pulmonary function and chest wall expansion than conventional cardiac rehabilitation alone.

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