Cardiovascular Innovations and Applications

Vol. 9 (2024) 11
ISSN 2009-8618
DOI 10.15212/CVIA.2023.0089

RESEARCH ARTICLE

Effects of Scalene Muscle Stretching on Slow Vital Capacity and Chest Expansion in Patients After Coronary Artery Bypass Grafting: An Interventional Study

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Received: 20 September 2023; Revised: 2 November 2023; Accepted: 15 November 2023

Abstract

Background: Coronary artery bypass grafting (CABG) is a coronary revascularization technique associated with diminished pulmonary function. During the first week after CABG, slow vital capacity (SVC) decreases by 30%–60%. Scalene muscles affect pulmonary function because they attach to the 1st and 2nd ribs. Shorter scalene muscles can decrease inhalation volume and chest expansion. Very few studies have assessed the effects of scalene stretching on SVC and chest expansion in patients post-CABG. Therefore, this study was aimed at determining the effects of scalene muscle stretching on SVC and chest expansion in such patients.
Methods: A total of 74 patients post-CABG (phase 2) meeting the inclusion criteria were randomly allocated to two groups: an intervention group (n = 30) performing scalene muscle stretching and a control group (n = 30) performing active neck exercise. Pre & Post SVC and chest expansion were measured in all patients. A total of 14 patients were excluded. Statistical analysis was conducted in SPSS software (version 20.0).
Results: SVC showed significant increase ($P < 0.05$) in the intervention group compared with the control group. Chest expansion was statistically non-significant between groups ($P > 0.05$).
Conclusion and clinical implications: Scalene muscle stretching improves SVC in patients post-CABG (phase 2). Hence, scalene stretching should be included in programs for improving respiratory function.

Keywords: Coronary artery bypass grafting; Chest expansion; Scalene stretching; Slow vital capacity

Abbreviations: CABG, Coronary Artery Bypass Grafting; PFT, Pulmonary Function Test; SVC, Slow Vital Capacity; FVC, Forced Vital Capacity, CG, Control Group, IG, Intervention Group, COPD, Chronic Obstructive Pulmonary Disease; EVC, Expiratory Vital Capacity; SCM, Sternocleidomastoid.

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Introduction

Coronary artery bypass grafting (CABG) is a successful coronary revascularization treatment in which atheromatous plaques in the coronary arteries are bypassed with harvested venous or arterial conduits [1, 2]. The bypass returns the blood supply to the ischemic myocardium, thus restoring function and viability, and alleviating anginal symptoms [1–3]. A serious postoperative consequence of CABG surgery is pulmonary function impairment [4, 5]. Pulmonary function is largely dependent on respiratory muscle strength [5] and consequently is severely impaired in the acute phase after CABG surgery [6–10]. Slow vital capacity (SVC) declines by 30%–60% during the first week after CABG surgery and remains lowered by 12% for as long as 1 year [5]. Pulmonary problems are the most common cause of morbidity and mortality after CABG surgery [5]. The causes of pulmonary function deterioration after CABG surgery are complex, including decreased ribcage expansion, uncoordinated chest wall motion, diaphragmatic dysfunction due to phrenic nerve injury, pleural fluid accumulation, and basal atelectasis [5, 11–13]. However, a decrease in pulmonary function can also be caused by respiratory muscle dysfunction [5]. Because respiratory muscles are skeletal muscles, they are susceptible to changes in circulatory variables that influence muscle mass and strength [5]. Peripheral skeletal muscle protein synthesis is greatly diminished immediately after CABG surgery, thus leading to considerable atrophy and muscle weakening in the first several weeks [5]. No relationship is known to exist between changes in pulmonary function after CABG surgery and changes in circulatory variables that affect (respiratory) muscle protein synthesis [5]. The diaphragm, intercostal muscles, and abdominal muscles are major respiratory muscles involved in resting respiration [14]. The sternocleidomastoid (SCM), scalene, trapezius, pectoralis major, pectoralis minor, and serratus anterior are respiratory support muscles involved in deep, forceful breathing [14]. If the neck muscles are difficult to control, or the joint range of motion is restricted, not only neck movement but also thoracic movement is restricted, thereby potentially impairing respiratory function [14]. Compared with the SCM, scalene movement has more action. Because the SCM is associated with the clavicle and sternum, whereas the scalene muscles are associated with the first and second ribs, scalene muscles have a greater influence on pulmonary function [14]. The scalene muscles comprise the anterior, middle, and posterior scalenes. The anterior scalene is attached to two-thirds of the first rib's medial point, whereas the middle scalene is attached to the superior surface of the first rib. Consequently, the first rib is lifted by the anterior and middle scalene muscles. The posterior scalene is associated with, and consequently elevates, the dorsal surface of the second rib [14]. Therefore, if the scalene muscles become shorter, the extent of thoracic lift decreases during inhalation, thus potentially decreasing inhalation volume [14]. Because median sternotomy is associated with short-term pulmonary impairment, pulmonary function can be measured both pre- and postoperatively [15–18]. Pulmonary function tests (PFTs) are a group of non-invasive diagnostics used to evaluate lung function. Forced vital capacity (FVC) and SVC are two means of evaluating vital capacity, both of which are major components of PFTs [15–18]. SVC can be determined during either a slow, mild maximal expiration after a maximal inspiration, or a maximal inspiration after a slow, gentle maximal expiration [15]. Both the FVC and SVC manoeuvres are performed at least three times and no more than eight times during a PFT [15]. Over the site of the median sternotomy after CABG, patients may experience incisional pain, which may be exacerbated by a forced vital capacity test. In contrast, the SVC test is easier for these patients to execute. Consequently, in this investigation, we used the SVC test to evaluate pulmonary function. Chest expansion was defined as the difference in thoracic girth after maximal inspiration and maximum expiration. This method for monitoring chest mobility is simple, affordable, and non-invasive, because it involves measurement with a measuring tape [19]. Very few studies have assessed the effects of stretching the scalene muscles on SVC and chest expansion in patients post-CABG. Therefore, the purpose of this study was to determine the effects of stretching the scalene muscles on SVC and chest expansion in patients post-CABG.

Materials and Methods

Each participant signed a written informed consent form. The study involved 74 patients recruited from a tertiary cardiac care centre (see Figure 1). On the basis of the standard deviation and mean from a pilot study and previous studies, sample size was calculated at power 0.80, with a confidence interval of 0.95 and an alpha level of 0.05. The study included patients who had undergone CABG and were in the 2–6-week postoperative period (phase 2).

Patients with postoperative wound infection, wound gapping, sternal instability, re-suturing, psychological disorders, or reluctance or inability to participate were excluded from the study.

The study used simple random sampling (chit method) to randomly assign patients to the control or intervention groups. No sex bias was present between groups. Each group comprised 30 participants. Fourteen patients were excluded, seven of whom were unable to follow the commands during the SVC measurement, four of whom had wound infection at the site of the sternal incision, and three of whom declined to provide written informed consent.

This study's outcome measures included SVC and chest expansion. Lung function testing equipment (Ganshorn Power Cube Diffusion+ system) was used to determine SVC (Figure 2(C)). Each patient was asked to take two or three normal tidal volume breaths before a deep, slow inhalation followed by

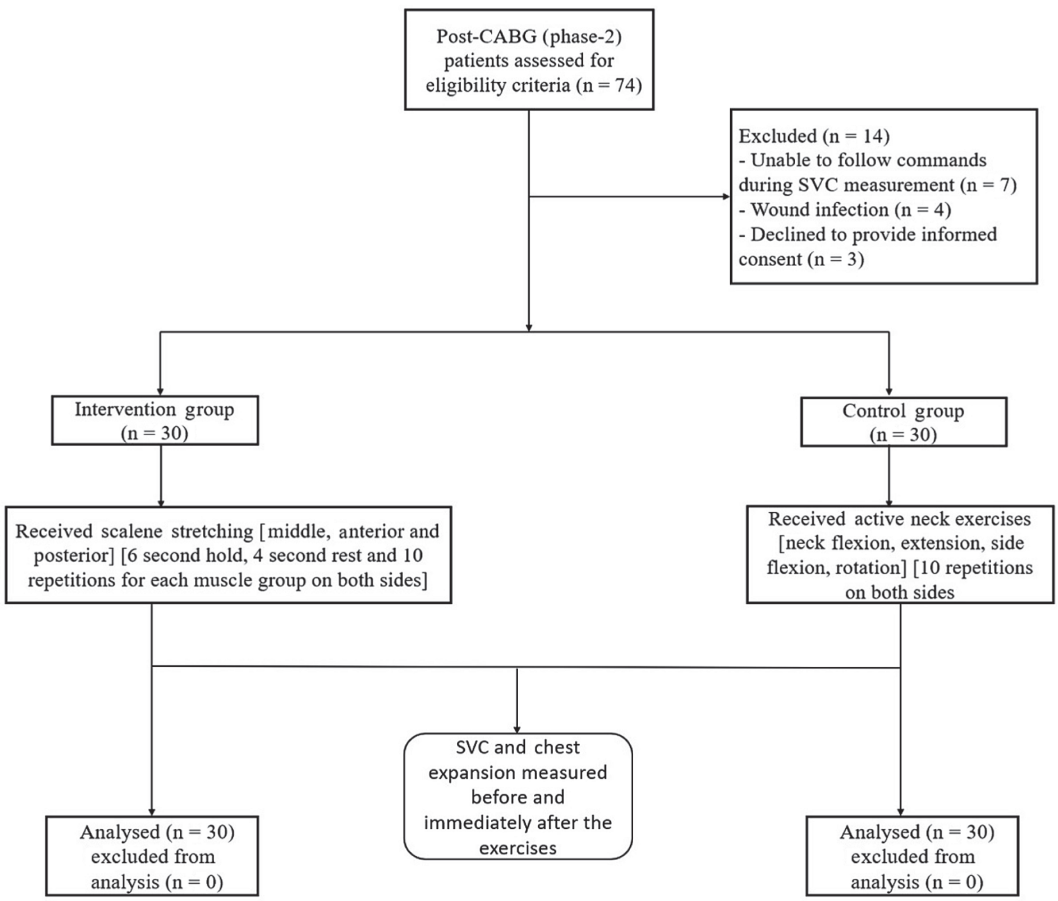

Figure 1 Procedure of the study.

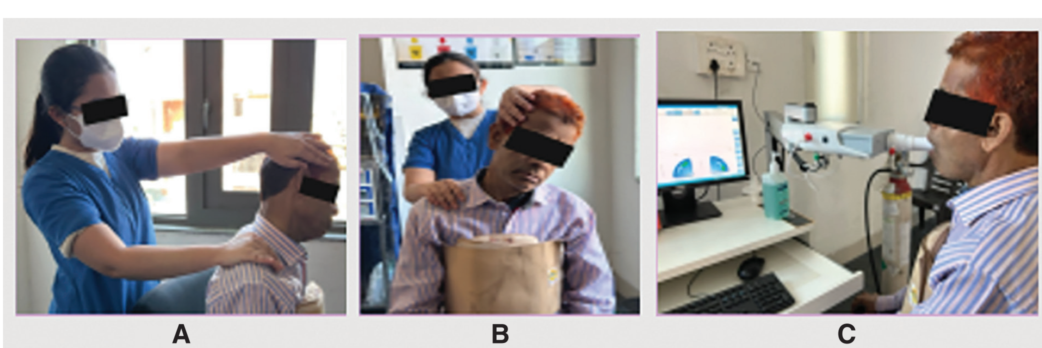

Figure 2 (A) and (B) Stretching of the right middle scalene muscle. (C) Patient performing SVC test.

a prolonged slow expiration. Three measurements were collected, and their average was used as the final measurement. As a precaution, each patient had a Coronavirus Disease 2019 rapid antigen test performed before SVC measurement. With the patient seated on a chair, chest expansion was measured with a tape measure at all three levels: axilla, nipple, and xiphisternum.

Before beginning the exercises, each participant's outcome measures were evaluated. To nullify the effects of posture, measures of midline neck length, lateral neck length, and tragus to wall distance were determined before the exercises in both groups [20, 21]. Each participant was seated on a chair with the back placed firmly against the back of the chair and facing forward for the neck length measurement. The midline neck length was measured from the upper border of the hyoid bone to the jugular notch. The distance from the angle of the mandible to the midportion of the ipsilateral clavicle was measured in the same position as the lateral neck length. For lateral neck length, an average of measurements from both sides was taken. The tragus-to-wall distance was measured as the horizontal distance between the right tragus and the wall, in participants standing with the heels and buttocks against the wall (to prevent pivoting), and knees extended and chin drawn in. A tape measure was used to determine each measurement.

Scalene muscles were stretched passively in the intervention group. The middle, anterior, and posterior scalene were stretched passively. Stretching was performed while the patient sat in a chair. The patient was requested to perform side flexion of the neck; slight overpressure was administered over the head toward the direction of stretching, and slight overpressure was administered over the same shoulder for stretching the middle scalene (Figure 2(A) and (B)). The same approach was used to stretch the anterior and posterior scalene with the neck slightly tilted posteriorly and anteriorly, respectively. Stretching was performed with a 6 second hold, 4 second rest, and ten repetitions for each muscle group on both sides, in the order of the middle, anterior, and posterior scalene muscles.

Active neck exercises were performed by the control group, including ten repetitions of neck flexion, neck extension, side flexion, and lateral rotation on both sides. Each activity was conducted in both groups with the patient's sternal incision secured with a chest binder.

SVC and chest expansion were assessed again immediately after the exercises in both groups, and statistical analysis was performed in IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY. The Kolmogorov-Smirnov test was used to confirm that the data were normally distributed. The statistical significance level was set at $P \leq 0.05$, and the confidence range was set at 95%. Paired t-test was used for within-group comparisons, whereas unpaired t-test was used for between-group comparisons.

Results

The baseline comparison between the control group and intervention group showed no significant differences; hence, both groups were comparable. Table 1 shows the baseline characteristics of both groups and the P-values.

Table 2 shows differences in outcomes after exercises between groups and within the intervention group, as well as P-values. The between-group comparison indicated a significant difference in SVC ($P < 0.05$) but not chest expansion ($P > 0.05$). The within group comparison showed a statistically significant difference in SVC ($P < 0.05$) but not chest expansion ($P > 0.05$) in the intervention group. No significant difference was observed in SVC and chest expansion within the control group ($P > 0.05$).

Figure 3(1) shows the between group comparison of post SVC. A statistically significant difference was observed in post SVC between the control and intervention groups ($P < 0.05$).

The analysis of post chest expansion between the control and intervention groups is illustrated in Figure 3(2). No statistically significant difference in chest expansion was observed at all three levels – axilla, nipple, and xiphisternum – between the control and intervention groups ($P > 0.05$). In addition, no statistically significant difference was found pre and post chest expansion at all three levels between groups ($P > 0.05$).

Within group analysis of pre and post SVC in the control and intervention groups is shown in Figure 3(3). No statistically significant difference between pre- and post-SVC was observed within the control group ($P > 0.05$). However, the intervention

Table 1 Baseline Characteristics.

	Intervention group (mean ± standard deviation)	Control group (mean ± standard deviation)	P-value (between groups)
Age (years)	59.83 ± 7.72	57.83 ± 8.07	0.33†
Body mass index (kg/m²)	24.94 ± 3.39	24.12 ± 2.09	0.26†
Midline neck length (cm)	7.77 ± 1.30	7.37 ± 0.96	0.18†
Lateral neck length (cm)	11.27 ± 1.55	10.87 ± 1.35	0.29†
Tragus to wall distance (cm)	11.03 ± 2.81	10.97 ± 3.42	0.93†
Pre SVC (litres)	1.98 ± 0.45	1.88 ± 0.56	0.45†
Pre chest expansion (at axilla) (difference in cm)	2.1 ± 0.40	2.07 ± 0.45	0.76†
Pre chest expansion (at nipple) (difference in cm)	1.43 ± 0.50	1.5 ± 0.50	0.61†
Pre chest expansion (at xiphisternum) (difference in cm)	1.13 ± 0.34	1.07 ± 0.25	0.39†

†Indicates P > 0.05.

Table 2 Differences in Slow Vital Capacity and Chest Expansion after Intervention.

	Intervention group (mean ± SD)	Control group (mean ± SD)	P-value (between groups)	P-value (within intervention group)
Post SVC (litres)	2.24 ± 0.58	1.89 ± 0.56	**0.02***	**0.04***
Post chest expansion (at axilla) (difference in cm)	2.3 ± 0.53	2.26 ± 0.44	0.79†	0.11†
Post chest expansion (at nipple) (difference in cm)	1.67 ± 0.54	1.7 ± 0.70	0.83†	0.09†
Post chest expansion (at xiphisternum) (difference in cm)	1.17 ± 0.38	1.03 ± 0.18	0.08†	0.72†

*Denotes statistically significant value; Indicates P < 0.05 means significant whereas > 0.05 means non-significant; †Indicates P > 0.05.

group showed a statistically significant difference between pre- and post-SVC (P < 0.05).

Discussion

After scalene stretching, patients' SVC improved significantly after CABG. The mean difference between post-SVC and pre-SVC was 0.26 (P < 0.05) in the intervention group and 0.01 (P > 0.05) in the control group. The mean difference between post-SVC of the intervention and control groups was 0.35 (P = 0.02).

This finding is in accordance with those from a study by Lee et al., who discovered a significant improvement in SVC after scalene stretching [14]. The experimental group exhibited a significant increase in expiratory vital capacity (EVC) (P < 0.05) and tidal volume (P < 0.05) in that study. The mean difference between post-EVC and pre-EVC in the experimental group was 0.2 (P < 0.05), whereas the mean difference between post-tidal volume and pre-tidal volume in the same group was 0.1 (P < 0.05). Expiratory reserve volume and minute ventilation increased after stretching, whereas inspiratory reserve volume decreased, but the differences were insignificant. The population of that study consisted of healthy female individuals. In the present study, the effects of scalene stretching on SVC were investigated in a different group, patients post-CABG. Figure 4 shows that patients with CABG have diminished pulmonary function because of neck muscle shortening resulting from protective flexed posture, median sternotomy, sternal retraction, and a forward head posture. Because the anterior and middle scalene muscles are attached to the first rib, and the posterior scalene is attached to the second rib, stretching of these muscles increases the lift of the upper thorax by increasing the length per unit time. The vertical diameter of the thorax consequently increases and leads to an increase in SVC, which in turn increases pulmonary function. Self-stretching of the cervical muscles enhances SVC, according to a study by Han et al. [22, 23].

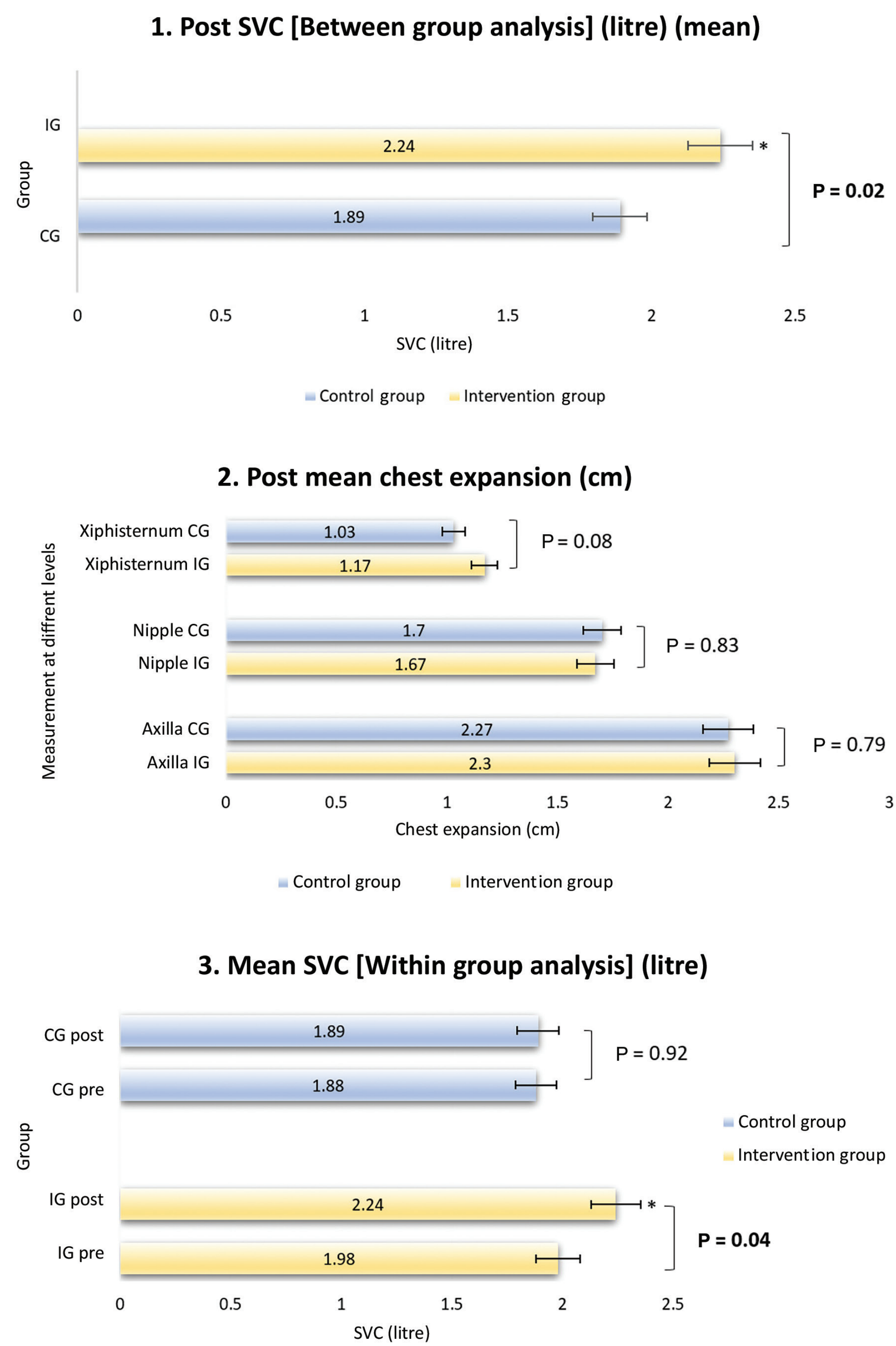

Figure 3 (1) Post slow vital capacity between group analysis. (2) Post chest expansion between group analysis. (3) Slow vital capacity pre and post within-group analysis. *Denotes the statistically significant value.

Furthermore, Han et al. found enhanced pulmonary function in individuals with allergic rhinitis as a result of SCM and scalene stretching and strengthening exercises [24]. Cho et al. have also found that neck muscle stretching and cervical joint motion exercises enhance pulmonary function in patients with stroke and tracheostomy tubes [25].

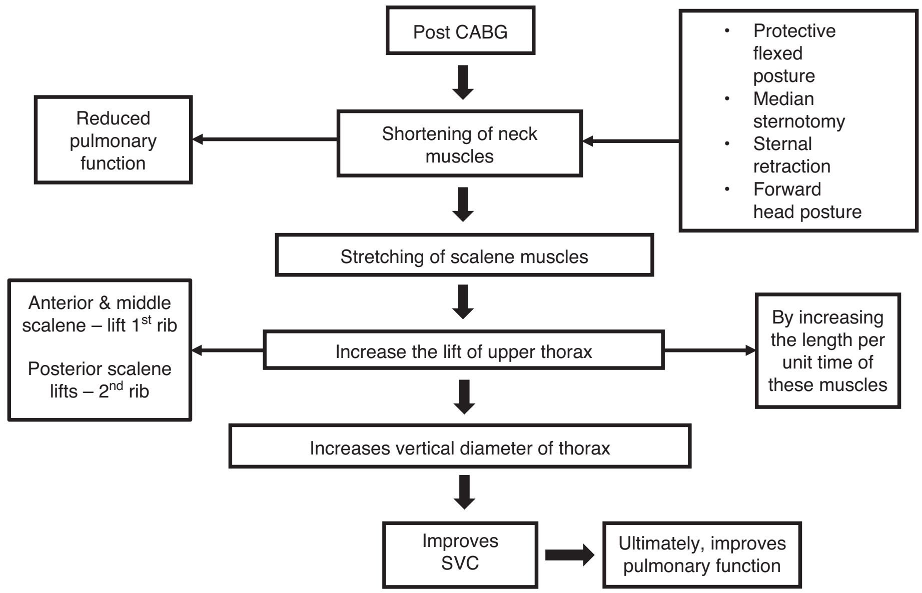

Figure 4 Mechanism for improvement in SVC after stretching of scalene muscles in post-CABG patients.

FVC can be improved by stretching the respiratory muscles. Patients with CABG are relatively likely to experience dynamic airflow blockage, which affects FVC but not SVC. Consequently, in this study, SVC was used as an outcome measure.

We observed no statistically significant difference on chest expansion. Rattes et al. have observed that in post-stroke patients with right hemiparesis, respiratory muscle stretching can produce transient increases in tidal volume and hemiparetic rib cage expansion [26]. Moreover, de Sá et al. have found that a simple and reproducible regimen for respiratory muscle stretching provides advantages in chest wall kinematics and ventilatory patterns in clinically stable patients with chronic obstructive pulmonary disease (COPD) [24].

According to a study conducted by Rehman et al., passive stretching of respiratory muscles can clinically improve the condition of patients with COPD, particularly in terms of chest expansion and 6-minute walk distance [27]. Previous research in a different population has indicated considerable improvement in axillary chest expansion after passive respiratory muscle stretching [24, 26, 27]. Because stretching all respiratory muscles is not advised in patients post-CABG (phase 2), this study investigated the effect of scalene stretching on chest expansion in these individuals. No statistically significant influence on chest expansion was observed. Because the scalene muscles are vertically oriented, they aid in increasing the vertical extent of the upper thorax but might have no effect on the anteroposterior mobility of the thorax. Consequently, stretching of the scalene muscles might not be beneficial in improving chest expansion.

Limitations of the Study

In this study, SVC improved in the intervention group as the result of stretching of scalene muscles; this stretching may increase the extent of lift of upper thorax. However, the increase in the vertical diameter of the thorax was not measured. The length-tension relationship of scalene muscles can be measured. An ultrasound guided procedure can also be used to assess the vertical movement of the thorax. Chest expansion was measured and indicated the antero-posterior expansion of the thorax.

Future Recommendations

In this study, most participants were men; future studies are recommended to include female patients. Because this study showed an immediate effect of scalene stretching, future recommendations can be made to identify the long-term effects of scalene stretching on SVC and chest expansion in patients post-CABG.

Conclusion and Clinical Implication

Stretching of the scalene muscles improves SVC in patients after CABG (phase 2). Hence, stretching of the scalene muscles should be included in programs for improving respiratory function.

Data Availability Statement

Data will be made available if required.

Ethics Statement

The study was approved by the institute's ethics committee (IEC: EC/Approval/9/Physio/21/06/2023). Written consent for submission and publication of this research has been obtained from the patients.

Author Contributions

Concepts: MV, MM, FO, BR. Design: MV, MM, FO. Definition of intellectual content: MV, MM. Literature search: MV, BR. Data acquisition: MV, MM, BR. Data analysis: MV, BR. Statistical analysis: MV. Manuscript preparation: MV, MM. Manuscript editing: MV. Manuscript review: MM, FO.

Acknowledgements

We thank our institute for supporting this research.

Conflict of Interest

The authors declare no conflicts of interest.

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