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Comparisons between chest trunk mobilization with sustained maximum inspiration and flow incentive spirometry on chest expansion, respiratory muscle strength, and functional exercise capacity in patients undergoing video-assisted thoracoscopic surgery

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Khanistha Wattanananont[1], Sasipa Buranapuntalug[2], Sira Laohathai[3]

[1] Cardiac Rehabilitation Center, Vajira Excellence Center, Vajira Hospital, Navamindradhiraj University, Bangkok, Thailand
[2] Physical Therapy Department, Faculty of Allied Health Sciences, Thammasat University, Pathumthani, Thailand
[3] Cardiothoracic Surgery Unit, Department of Surgery, Faculty of Medicine Vajira Hospital, Navamindradhiraj University, Bangkok, Thailand

Abstract

Introduction. Chest trunk mobilization with sustained maximum inspiration (SMI) and flow incentive spirometry (flow IS) are breathing techniques that mostly apply to patients undergoing video-assisted thoracoscopic surgery (VATS). The purpose of this study was to determine the effects of chest trunk mobilization with SMI and flow IS on chest expansion, respiratory muscle strength, and functional exercise capacity in patients undergoing VATS.

Methods. Sixty VATS patients were randomly allocated into chest trunk mobilization with SMI (n = 30) and flow IS (n = 30) groups. Each group performed a physical therapy program preoperatively and 4 days post-operatively. Chest expansion at upper, middle, and lower levels, inspiratory and expiratory muscle strengths, and functional exercise capacity were determined at pre- and post-VATS.

Results. In both groups, chest expansion at all levels, expiratory muscle strength, and distance of the 6MWT significantly increased ($p < 0.05$) post-operatively compared to pre-operative assessments, although there was no significant difference between groups. In addition, inspiratory muscle strength significantly improved from baseline in both groups ($p < 0.05$), but the flow IS group showed a greater increase than the chest trunk mobilization with the SMI group (78.17 ± 24.16 and 65.57 ± 20.39 cm H_2O, respectively, $p < 0.05$).

Conclusions. Chest trunk mobilization with SMI and flow IS can improve chest expansion at all levels, as well as respiratory muscle strength and the distance of the 6MWT. However, flow IS enhances inspiratory muscle strength to a greater extent than chest trunk mobilization with SMI. Ultimately, both techniques can be applied effectively in patients undergoing VATS.

Key words: video-assisted thoracoscopic surgery, respiratory muscle training, breathing exercises, physical therapy, incentive spirometer

Introduction

Video-assisted thoracoscopic surgery (VATS) or thoracoscopy is a form of thoracic surgery that is minimally invasive compared to thoracotomy. This technique, which is an alternative to open surgery, can reduce post-operative pulmonary complications (PPCs) such as pain, atelectasis, and duration of the chest tube and decrease the length of hospitalization [1, 2]. Moreover, a previous study has reported that VATS is safer, more reproducible, and more effective than open surgery [1]. Patients who underwent VATS showed a lower surgical injury rate compared to those undergoing traditional pulmonary surgery such as thoracotomy [3, 4]. However, PPCs have been reported in patients with VATS [3–5]. Complications from VATS still occur post-operatively from the incision and intercostal drainage (ICD), which may affect pain and cause an ineffective cough, shortness of breath, and other complications, such as dyspnea, decreased chest expansion, respiratory muscle weakness, impaired airway clearance, poor posture, reduced shoulder range of motion, and limitations in daily activities [2, 3, 5]. Therefore, the role of physical therapy (PT) programs is to prevent or reduce the risk of post-operative complications, as these exercises can improve pulmonary ventilation, improve respiratory functions, remove secretions, prevent shoulder joint stiffness, and help restore daily activities and quality of life [3, 6, 7]. This program should be applied before and after operations to prevent and reduce PPCs [1, 3, 7].

Poor pulmonary ventilation and respiratory dysfunction are the primary PPCs experienced by patients who are post-operative in the hospital phase which affects their exercise capacity [3, 5]. A PT program should be considered for the prevention of the PPCs that may affect the clinical status of patients [1]. Breathing exercises that improve pulmonary ventilation and restore respiratory muscle function constitute a part of the PT program [2, 5]. These include costal breathing exercises, diaphragmatic breathing exercises, chest trunk mobilization, sustained maximal inspiration (SMI), and flow incentive spirometry (flow IS). Flow IS is a respiratory device popular in hospitals because it has visual feedback of airflow [6, 8] and it is effective in reducing PPCs when compared with no PT treatment [9]. Using this device, the patient inspires deeply and holds their breath at maximal inspiration until a ball is lifted for as long as possible [8, 9]. However, a previous study found that flow IS devices can stimulate the

Correspondence address: Sasipa Buranapuntalug, Physical Therapy Department, Faculty of Allied Health Sciences, Thammasat University, 99 Phahonyothin Road, Khlong Luang, Pathumthani 12120, Pathumthani, Thailand, e-mail: beesasipa38@gmail.com; https://orcid.org/0000-0002-3894-4109

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activity of accessory muscles and increase respiratory rate (RR) more than other breathing exercises [10, 11], the consequence of which is greater work of breathing and increased breathlessness. Interestingly, the breathing technique of flow IS is similar to the SMI technique, in which the patient breathes deeply until maximal inspiration and holds for 3 s [8]. This deep inspiration is also similar to the breathing pattern in the chest trunk mobilization technique. Moreover, chest trunk mobilization techniques with SMI and flow IS techniques have the same objective of enhancing pulmonary ventilation and respiratory muscle function [3, 7, 8]. The flow IS device may not be accessible to all patients, whereas, chest trunk mobilization with SMI is a breathing exercise that patients can practice by themselves [8]. Given the disadvantage of flow IS, chest trunk mobilization with SMI techniques might be an interesting alternative for clinical practice.

Therefore, the objectives of this study were to compare the effects of chest trunk mobilization with SMI and flow IS on chest expansion, respiratory muscle strength, and functional exercise capacity in patients undergoing VATS.

Subjects and methods

Participants

Patients undergoing VATS, male and female, aged 18–60 years, who voluntarily participated were included in this study. The sample size calculation from G*power 3.1.9.4 was performed based on a power of 0.95, a significance level of 0.05 [12], and a drop-out rate of 10%. Resulting in the total number of participants needed were 60. All participants were recruited from Vajira hospital and screened by a chest physician. The inclusion criteria included an ability to perform chest trunk mobilization with SMI and flow IS correctly and an ability to walk independently without aid. Individuals were excluded from this study if they had cardiac or neuromuscular problems, impaired sitting balance, or uncontrolled hypertension (> 140/90 mm Hg). Informed consent was obtained from all participants included in this study. All participants were randomized by the block randomization method into a chest trunk mobilization with a SMI group ($n = 30$), and flow IS group ($n = 30$).

Study design

This study used a randomized controlled trial design divided into chest trunk mobilization with SMI and flow IS groups. Data were collected between May 2020 and December 2021.

Breathing techniques

Chest trunk mobilization with SMI

The participants performed chest trunk mobilization with SMI by flexing the shoulder while inspiring through the nostrils until maximal inspiration and then holding for 3 s. They then moved their arms to the starting point while expiring through the nostrils (Figure 1A). All subjects in this group performed the exercise 10 times per set, with three sets per day.

Flow incentive spirometry (flow IS)

The participants in the flow IS group practised by holding the tri-ball incentive spirometer (a+msc, GaleMed Corporation, Taiwan) in an upright position, in line with eye level, and parallel to the ground (Figure 1B). They breathed in deeply and held for 3 s as the balls were lifted, then breathed out. All subjects were asked to perform this activity 10 times per set, three sets per day [13].

Training program

All participants received the physical therapy program both before and 4 days after their surgery. The program's structure remained consistent across all participants, with the exception of the specific breathing exercises employed in the chest trunk mobilization with SMI and flow IS. The details of the PT program are presented in Table 1.

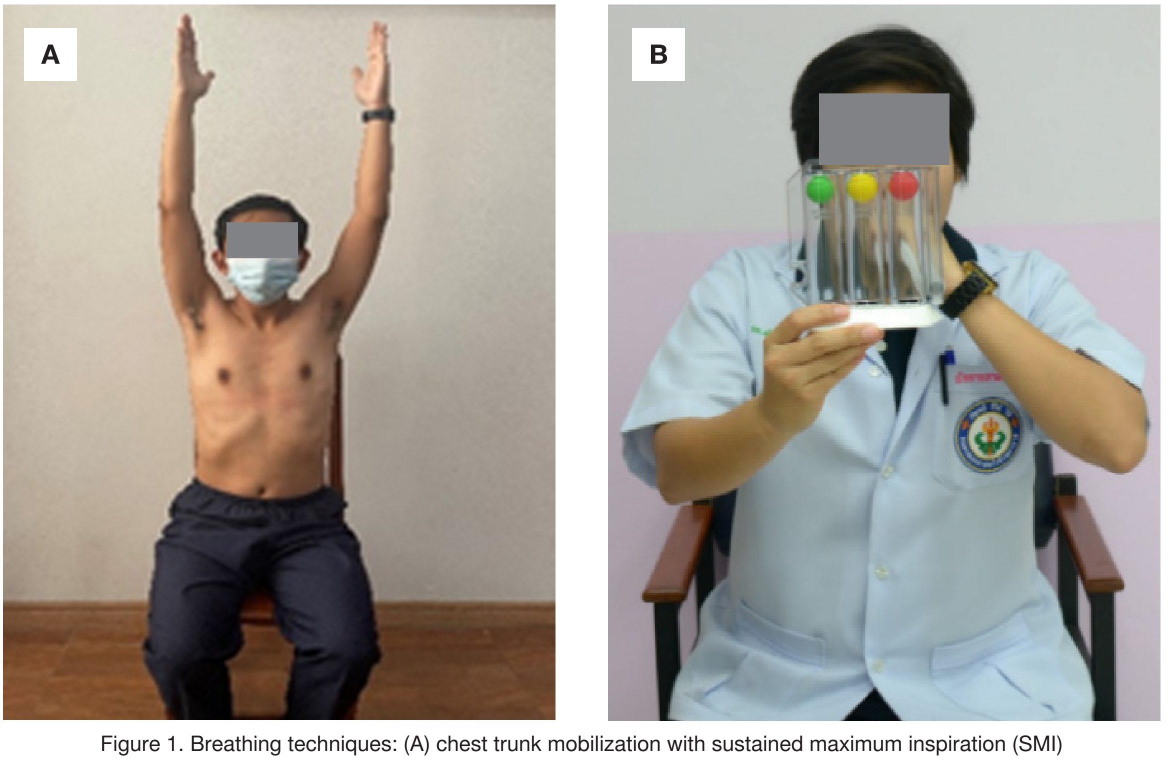

Figure 1. Breathing techniques: (A) chest trunk mobilization with sustained maximum inspiration (SMI) and (B) flow incentive spirometer (flow IS)

Table 1. Physical therapy program for both groups

Day	Chest trunk mobilization with SMI group	Flow IS group
Pre-operative	– Explained operative procedure and physical therapy program – Chest trunk mobilization with SMI training	– Explained operative procedure and physical therapy program – Flow incentive spirometer training
1st day post-operative	Physical therapy program: Practice in an upright position on the bed 1. Diaphragmatic breathing exercises (10 times/set) 2. Cough training 3. Active exercises (10 times/exercise): – ankles: dorsi/plantar flexion – hips and knees: flexion/extension – wrists: flexion/extension – elbows: flexion/extension – shoulder: flexion/extension 4. Chest trunk mobilization with SMI (10 times/set and 3 sets/day)	Physical therapy program: Practice in an upright position on the bed 1. Diaphragmatic breathing exercises (10 times/set) 2. Cough training 3. Active exercises (10 times/exercise): – ankles: dorsi/plantar flexion – hips and knees: flexion/extension – wrists: flexion/extension – elbows: flexion/extension – shoulder: flexion/extension 4. Flow incentive spirometer (10 times/set and 3 sets/day)
2nd day post-operative	Same as 1st day post-operative but in sitting position on bedside	Same as 1st day post-operative but in sitting position on bedside
3rd day post-operative	– Same as 2nd day post-operative – Marching in place 10 times and walking around the bed	– Same as 2nd day post-operative – Marching in place 10 times and walking around the bed
4th day post-operative	– Same as 3rd day post-operative – Walking 100 m	– Same as 3rd day post-operative – Walking 100 m

SMI – sustained maximum inspiration, Flow IS – flow incentive spirometry
The training program depended on the conditions and performance of each participant

Measurement and instrumentation

Respiratory muscle strength

Respiratory muscle strength was measured by a respiratory pressure meter (RPM01, Micro Medical Ltd., United Kingdom), which is calibrated using industry-wide data every 2 years in accordance with established guidelines. This method is one of the most standard and widely used methods for measuring respiratory muscle strength and is recommended by the American Thoracic Society/European Respiratory Society (ATS/ERS) [14, 15]. The respiratory pressure meter (RPM01) measured upper airway pressure from the mouth during maximal voluntary inspiratory and expiratory efforts generated by the respiratory muscle [16]. Inspiratory muscle strength was represented by maximal inspiratory pressure (MIP), and expiratory muscle strength was represented by (MEP). MIP and MEP were tested separately. After the manoeuvre was explained, participants were asked to sit comfortably. While wearing a nose clip, participants were required to close their lips around the mouthpiece. For MIP, the subjects performed maximal exhalation to residual volume, followed by a maximum inspiration, and sustaining the pressure for at least 1 s. For MEP, they were instructed to inhale to total lung capacity, then perform a maximum expiration and maintain the pressure for at least 1 s [14]. Each manoeuvre was performed sequentially with at least 1-minute resting intervals. The highest value of three measurements with 5% variability was recorded [14]. These measurements were collected by a single research assistant.

Chest expansions

A tape measure was used to determine chest expansion in centimetres. This study measured three parts of the lungs [17] as follows:

– Upper – measured at the 3rd intercostal space at the midclavicular line and 5th thoracic spinous process.

– Middle – measured at 5th intercostal space at the midclavicular line and 7th thoracic spinous process.

– Lower – measured at the tip of the xiphoid process and 10th thoracic spinous process

All participants were asked to sit comfortably and then fully expire and inspire for each measurement. The average value of three measurements at each level was recorded [17]. These parameters were assessed by research assistant 1, who has experience and is a specialist in using this instrument.

Functional exercise capacity

The 6-minute walk test (6MWT), an approved clinical exercise test, was performed to evaluate functional exercise capacity. This test was conducted in a 30-metre indoor hallway marked at every metre. All participants were monitored for oxygen saturation (SpO_2), RR, heart rate (HR), dyspnea level (Modified Borg Dyspnea Scale), and (BP) for safety pre- and post-6MWT. Distance was the measured variable in this test and was evaluated pre- and post-VATS. All vital signs were checked during the resting period, ensuring they were in a normal range for resting while in a sitting position. Participants were then asked to walk as far as possible within a 6-minute period. Participants were allowed to slow down or stop whenever they felt uncomfortable and continue walking once recovered, although the timer was not paused. The total distance and number of rests were recorded. After the test, SpO_2, RR, HR, dyspnea level, and BP were assessed again in both groups [18–20]. This assessment was performed by research assistant 2 who was well-trained to perform this assessment.

Procedure

Patients undergoing VATS were recruited in this study according to the inclusion and exclusion criteria. All participants were randomized into chest trunk mobilization with SMI, and flow IS groups. In both groups, participants were tested for chest expansion, respiratory muscle strength, and functional exercise capacity by 6MWT before and after the training program. They underwent the training program (Table 1) before VATS as well as on post-operative days 1–4.

Data analysis

Data were analysed using IBM SPSS Statistics for Windows (Version 28.0. Armonk, NY: IBM Corp). The Shapiro–Wilk test was done for evaluation of the normal distribution of the data. Demographic data, causes, and type of VATS were analysed using an unpaired *t*-test. All variables were analysed using Two Way Mixed ANOVA to compare within-group variables (pre- vs. post-VATS) and between groups (chest trunk mobilization with SMI and flow IS groups). The statistical significance was set at $p < 0.05$.

Results

Participants

Sixty patients undergoing VATS ($n = 60$) were included in this study. All participants completed the study with no cases of drop-out or adverse events. The demographic data in both groups are shown in Table 2. There were no significant differences between chest trunk mobilization with SMI, and flow IS groups at baseline. In addition, there were no significant differences in causes of surgery and type of VATS between the groups.

Effects of different breathing techniques on respiratory muscle strength

At baseline, MIP and MEP were not significantly different in chest trunk mobilization between the SMI and flow IS groups (Figure 2). Interestingly, the MIP and MEP on post-operative day 4 increased significantly from baseline in chest trunk mobilization with the SMI group (mean change in MIP: +14.10 cm H_2O, $p < 0.001$; mean change in MEP: +14.90 cm H_2O,

Table 2. Demographic data and causes and type of VATS in the chest trunk mobilization with SMI and flow IS groups

Characteristics	Chest trunk mobilization with SMI group ($n = 30$)	Flow IS group ($n = 30$)	*p*-value
Age (years), mean ± *SD*	51.77 ± 14.98	52.53 ± 18.09	0.859
Weight (kg), mean ± *SD*	58.25 ± 13.14	62.16 ± 15.16	0.290
Height (cm), mean ± *SD*	160.47 ± 8.33	162.00 ± 9.86	0.518
Body mass index (kg/m^2), mean ± *SD*	22.70 ± 5.41	23.57 ± 4.70	0.507
Sex (*n*), male/female	14/16	16/14	0.797
History of smoking (*n*), no/yes	23/7	22/8	1.000
Causes of surgery (diseases)			
lung cancer	11	14	0.736
myasthenia gravis	3	3	
empyema	4	5	
pneumothorax	12	8	
Type of VATS			
lobectomy	11	14	0.557
thymectomy	3	3	
decortication	4	6	
bullectomy	12	7	
Chest expansion			
upper part (cm), mean ± *SD*	2.77 ± 0.24	2.86 ± 0.21	0.129
middle part (cm), mean ± *SD*	2.90 ± 0.35	3.02 ± 0.53	0.334
lower part (cm), mean ± *SD*	2.96 ± 0.26	3.01 ± 0.48	0.641
Respiratory muscle strength			
maximal inspiratory pressure (cm H_2O), mean ± *SD*	51.47 ± 16.58	60.07 ± 20.77	0.082
maximal expiratory pressure (cm H_2O), mean ± *SD*	57.60 ± 18.78	67.17 ± 20.99	0.068
6-minute walking distance (m), mean ± *SD*	272.93 ± 57.17	291.27 ± 107.29	0.402

SMI – sustained maximum inspiration, Flow IS – flow incentive spirometry

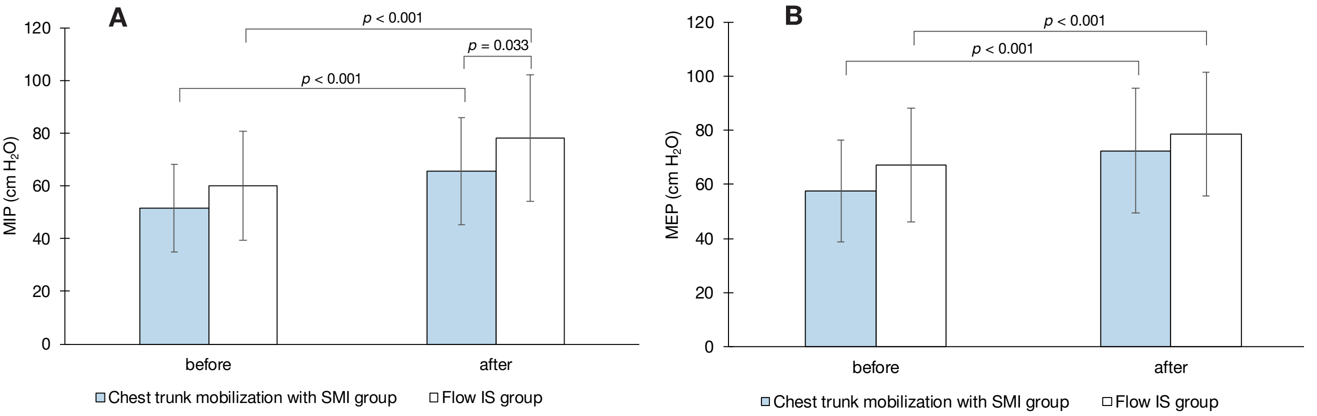

Figure 2. Respiratory muscle strength: (A) maximal inspiratory pressure or MIP and (B) maximal expiratory pressure or MEP in chest trunk mobilization in the SMI (grey bar) and flow IS groups (white bar) before and after training
The *p*-value was analysed statistically using two-way mixed ANOVA. Each bar represents the mean ± *SD*

$p < 0.001$) and flow IS group (mean difference of MIP: +18.10 cm H_2O, $p < 0.001$; mean change in MEP: +11.53 cm H_2O, $p < 0.001$). A significant difference in MIP was demonstrated in chest trunk mobilization between the SMI and flow IS groups ($p = 0.033$) after the training program, although no significant difference was observed in MEP.

Effects of different breathing techniques on chest expansion

The chest expansion of the upper, middle, and lower chest was not significantly different in chest trunk mobilization between the SMI and flow IS groups at baseline (Table 3). Within both groups, the expansions of all parts of the chest at post-operative day 4 were significantly greater than those at baseline. In contrast, no chest expansions were significantly different between groups after training. These results indicate no significant effects between different types of breathing techniques on chest expansion.

Effects of different breathing techniques on functional exercise capacity

The results of the 6MWT at baseline held no significant difference between breathing exercises and flow IS groups (Table 3). Compared to baseline, the distance covered in the 6MWT increased significantly in both groups after VATS on post-operative day 4 (chest trunk mobilization with SMI group: +32.53 m; flow IS group: +31.30 m). There was no significant difference in 6MWT results between groups after post-operative day 4. These findings suggest that no significant effect exists between breathing techniques on functional exercise capacity.

Discussion

Breathing exercise is a part of the PT program that is used to improve pulmonary ventilation and relieve the PPCs of VATS. Both types of breathing exercises demonstrated in this study are commonly used in PT programs. Therefore, we aimed to evaluate the efficacy of chest trunk mobilization with SMI versus flow IS for recovery of pulmonary respiration after VATS.

Both chest trunk mobilization with SMI and flow IS can improve the strength of respiratory muscles. Renault et al. [21] and Romanini et al. [22] supported these results in that flow IS and breathing exercises impose work on the respiratory muscles, recruiting greater motor units. The results of this study suggested that both breathing techniques recruited respiratory muscle motor units, effectively increasing inspiratory and expiratory muscle strength. Interestingly, flow IS, which requires an increased inspiratory effort and has visual stimulation from balls during the active inspiration phase [22], affected a significant improvement in inspiratory muscle strength compared to that in the chest trunk mobilization with the SMI group. Lunardi et al. [11] found that flow IS can activate inspiratory muscles in elderly and healthy adults. Gay-

Table 3. Comparison of chest expansion and distance of 6MWT in chest trunk mobilization of the SMI and flow IS groups before and after training

Characteristics	Chest trunk mobilization in the SMI group (*n* = 30)		*p*-value within group*	Flow IS group (*n* = 30)		*p*-value within group*	*p*-value between groups after training
	before (mean ± *SD*)	after (mean ± *SD*)		before (mean ± *SD*)	after (mean ± *SD*)		
Chest expansion							
upper part (cm)	2.77 ± 0.24	3.14 ± 0.31*	< 0.001	2.86 ± 0.21	3.32 ± 0.43*	< 0.001	0.096
middle part (cm)	2.90 ± 0.35	3.42 ± 0.35*	< 0.001	3.02 ± 0.53	3.59 ± 0.58*	< 0.001	0.177
lower part (cm)	2.96 ± 0.26	3.60 ± 0.39*	< 0.001	3.01 ± 0.48	3.69 ± 0.61*	< 0.001	0.131
6 minute walk distance (m)	272.93 ± 57.17	305.47 ± 58.19*	< 0.001	291.27 ± 107.29	322.57 ± 120.23*	0.001	0.486

SMI – sustained maximum inspiration, Flow IS – flow incentive spirometry
Data reported as statistical comparisons were performed using two-way mixed ANOVA
* significant difference between before and after within the groups ($p < 0.05$)

athiri and Anandhi [12] revealed that flow IS actively recruits the diaphragm and inspiratory muscles; thus, flow IS may activate respiratory muscles to a greater extent than chest trunk mobilization with SMI.

Our results showed respiratory muscle strength was improved by both techniques, although flow IS can activate inspiratory muscles more so than chest trunk mobilization with SMI.

Effects of different breathing techniques on chest expansion

The results of this study reveal that both breathing techniques increased chest expansion at all levels; however, there was no difference in effect between breathing techniques. A previous study by Yamaguti et al. [6] showed that diaphragmatic mobility increased during diaphragmatic breathing and flow IS, in which, similar to our study, participants inhaled deeply and slowly and held maximal inspiration for 3 s. Lunardi et al. [11] revealed that flow IS can activate inspiratory and diaphragmatic muscle groups. This implies how the flow IS in this study could stimulate the expansion of the thoracic wall in all dimensions – through activation of diaphragmatic and inspiratory muscles [6, 12, 23, 24]. In addition, the chest trunk mobilization with 3 s of SMI mobilizes the chest wall in all dimensions through breathing and simultaneous shoulder movement. Both breathing techniques can reduce pleural pressure (Ppl) during inspiration and allow for a greater air intake into the lungs [12, 25]. Therefore, both breathing exercises and flow IS can improve chest expansion at all levels of the lungs. However, there was no difference in the effect of breathing techniques on chest expansion; both techniques can be applied to patients with similar results in this regard.

Effects of different breathing techniques on functional exercise capacity

As the last objective of this study, the effect of both breathing techniques on functional exercise capacity was determined by 6MWT pre- and post-VATS. Compared to pre-operative measurements, there were significantly improved results (increased walking distances) from both techniques, although no difference was observed between breathing techniques. The improvement in the distances of 6MWT with both breathing techniques may be a response to improved oxygen transport from the lungs to the body, increasing functional performance from baseline [26]. However, while the distance in both groups was improved, there were less than minimal clinically important differences (MCID) in respiratory patients [27]. Therefore, there was no differential effect between breathing techniques on functional exercise capacity. However, both chest trunk mobilization with SMI and flow IS can be applied in clinical practice.

Further study

Respiratory and accessory muscle recruitment should be examined by electromyography breathing exercises or by other devices. Other devices for improved pulmonary ventilation and functional exercise capacity, such as volume incentive spirometer, power breathing, and other breathing exercises, should be investigated for comparison. Age and BMI should be controlled in the same range to prevent the differences arising from physiological responses, particularly in elderly participants and those with a normal BMI.

Limitations

This study did not directly assess respiratory and accessory muscle activities to determine muscle recruitment while performing breathing techniques. Furthermore, the demographic data such as BMI and age were not controlled for in this study. These factors could potentially impact the physiological responses. Therefore, it is recommended that future studies focus on controlling for age and BMI to prevent potential confounding effects on the observed physiological responses.

Conclusions

The results in this study revealed that chest trunk mobilization with SMI and flow IS enhanced chest expansion at all levels, as well as respiratory muscle strength and functional exercise capacity when compared to pre-VATS measurements. In addition, flow IS can improve inspiratory muscle strength more than chest trunk mobilization with SMI. Chest trunk mobilization with SMI was equivalent to flow IS for all outcomes when compared to pre-operative status. This suggests that chest trunk mobilization with SMI might be an alternative technique, particularly in cases where acquiring the flow IS device may not be feasible. Based on our findings, both chest trunk mobilization with SMI and flow IS can be recommended as practices by VATS patients pre- and post-operatively, for patients at risk for PPCs.

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Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the Ethics Committee on Human Experiment of Faculty of Medicine Vajira hospital, Navamindradhiraj University (approval No.: COA 054/2563).

Informed consent

Informed consent has been obtained from all individuals included in this study.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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