EFFECT OF COMBINED CHEST MOBILIZATION WITH PHYSICAL THERAPY TREATMENT ON CHEST EXPANSION AND PAIN IN PATIENTS UNDERGOING LOBECTOMY: A RANDOMIZED CONTROLLED TRIAL

NAPAPORN VAEWTHONG

Graduate School Srinakharinwirot University

2020

ผลของการฝึกการเคลื่อนไหวทรวงอกร่วมกับการรักษาทางกายภาพบำบัดต่อการขยายตัวของทรวงอกและอาการปวดแผลในผู้ป่วยหลังผ่าตัดกลีบปอด: การศึกษาแบบสุ่ม

นภาพร แววทอง

ปริญญานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตร
วิทยาศาสตรมหาบัณฑิต สาขาวิชากายภาพบำบัด
คณะสหเวชศาสตร์ มหาวิทยาลัยศรีนครินทรวิโรฒ
ปีการศึกษา 2563

EFFECT OF COMBINED CHEST MOBILIZATION WITH PHYSICAL THERAPY TREATMENT ON CHEST EXPANSION AND PAIN IN PATIENTS UNDERGOING LOBECTOMY: A RANDOMIZED CONTROLLED TRIAL

NAPAPORN VAEWTHONG

A Thesis Submitted in Partial Fulfillment of the Requirements

for the Degree of MASTER OF SCIENCE

(Physical Therapy)

Faculty of Health Science, Srinakharinwirot University

2020

THE THESIS TITLED

EFFECT OF COMBINED CHEST MOBILIZATION WITH PHYSICAL THERAPY TREATMENT ON CHEST EXPANSION AND PAIN IN PATIENTS UNDERGOING LOBECTOMY: A RANDOMIZED CONTROLLED TRIAL

BY

NAPAPORN VAEWTHONG

HAS BEEN APPROVED BY THE GRADUATE SCHOOL IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE MASTER OF SCIENCE IN PHYSICAL THERAPY AT SRINAKHARINWIROT UNIVERSITY

(Assoc. Prof. Dr. Chatchai Ekpanyaskul, MD.)

Dean of Graduate School

ORAL DEFENSE COMMITTEE

..... Major-advisor

(Asst. Prof.Sukalya Kritsnakriengkrai, Ph.D.)

..... Chair

(Nantinee Nualnim, Ph.D.)

..... Committee

(Asst. Prof.Chatchada Chinkulprasert, Ph.D.)

Title	EFFECT OF COMBINED CHEST MOBILIZATION WITH PHYSICAL THERAPY TREATMENT ON CHEST EXPANSION AND PAIN IN PATIENTS UNDERGOING LOBECTOMY: A RANDOMIZED CONTROLLED TRIAL
Author	NAPAPORN VAEWTHONG
Degree	MASTER OF SCIENCE
Academic Year	2020
Thesis Advisor	Assistant Professor Sukalya Kritsnakriengkrai , Ph.D.

The objective of this study is to compare the effects of combined chest mobilization with physical therapy treatment on chest expansion, pain and functional capacity among patients undergoing a lobectomy. The thirty-six patients with lobectomies were randomly divided into two groups, the control (n=18) and experimental groups (n=18). All patients received standard physical therapy treatment, including breathing exercises, cough/huff training, shoulder range of motion exercise, and early mobilization. The experimental group received chest mobilization combined with physical therapy treatment. The hemi-thorax chest expansion and pain score were measured on the preoperative day and the first to the third of the postoperative days. The six-minute walk test was measured on both preoperative and discharge days. The data were analyzed using two-way mixed ANOVA. The significant difference level was set at $P<0.05$ and the results showed that the chest expansion on operated and non-operated sides of both the control and experimental groups significantly decreased on the first postoperative day ($P<0.05$), gradually increased and nearly reached the baseline on the third postoperative day. Only the lower chest expansion on the non-operated side returned to baseline on the third postoperative day for both groups ($P<0.05$). A moderate-to-severe postoperative pain was found on the first operative day among groups and the pain score was reduced on the second and the third postoperative days ($P<0.05$). The six-minute walk distance represented functional capacity was significantly decreased after the lobectomy ($P<0.05$). All of the variables revealed a non-significant difference between the control and experimental groups. The conclusion of this study was that combined chest mobilization with physical therapy treatment was not more effective than standard physical therapy treatment on chest expansion, pain and functional capacity in the early period after lobectomy.

Keyword : Combined chest mobilization, Physical therapy treatment, Chest expansion, Lobetomy

ACKNOWLEDGEMENTS

This complete thesis would not be possible without the guidance and the help of several people. I would like to express appreciation to Asst. Prof. Dr. Sukalya Kritsnakriengkrai, my advisor for her advice and encouragement to the achievement of this thesis.

Many thanks to all participants of this study for their selflessness time to participate in this thesis.

I was express special thanks to Ms. Nattha Tithasiri, who was the former leader of the Rehabilitation Department at Central Chest Institute of Thailand for her support and recommendation from initial to final this thesis.

Grateful to the respiratory physiotherapy team, Central Chest Institute of Thailand, Nonthaburi for screening the participants, facility support, and help to solve the many problems. Special thankfulness to Ms. Juthamas Supopak, Ms. Thidarat Khaowpiw for my research assistants during the data collection.

Special thanks to Srinakharinwirot University for supporting funds in this thesis.

Finally, I wish to my deepest gratitude to my family, my co-worker, and my friend who always supports everything during academic life.

NAPAPORN VAEWTHONG

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

CHAPTER 1
INTRODUCTION

Background

During the period from 1999 to 2006, over 49,000 patients received lung resection (1). Lung resection is a technique for removing the abnormal tissue in the lung including wedge resection, segmentectomy, lobectomy, and pneumonectomy. The surgical approach consists of thoracotomy, video-assist thoracic surgery (VATS), and other techniques (1). The VATS technique has been increasing among patients undergoing lung resection due to less aggravation of pain, lower complication, and staying in a shorter time in the hospital (2). However, the recent study found that the different surgical approach was not associated with respiratory muscle strength and the incidence of postoperative pulmonary complications (3).

Postoperative pulmonary complications (PPCs), commonly occurred in post pulmonary surgery, and are associated with the length of hospital stay (LOS), morbidity, mortality, and healthcare costs in the public health system. The incidence of PPCs has been reported with from <1% to 23% in a major surgery (4). Approximate 11.5% of the incidence of PPCs was found in patients undergoing thoracic and abdominal surgeries (5).

Furthermore, post pulmonary surgery affected to reduce lung volume, diffusing capacity, and exercise capacity (6-8). The postoperative forced expiratory volume in 1 second (FEV_1) is the most common predictor of co-morbidity and postoperative complications (9). The decrease in FEV_1 after pulmonary surgery is related to the difference in lung volume resection. (8, 10).

The intercostal drainage (ICD) is usually inserted in the pleural cavity after the lung resection to release air and fluid. The patients being on ICD has experienced more static and dynamic pain than the ones from which the ICD has been removed, whether or not approaching by VATS or thoracotomy (11). The pain from the ICD insertion would limit chest expansion, consequence to reduce lung volume.

The lung volume is generated by the respiratory muscles, which consists of the inspiratory and expiratory muscles (12). However, the respiratory muscle will be impaired by muscle relaxant drugs administered during operation, which causes the loss of muscle tone. The respiratory muscle dysfunction affects the reduction of FEV_1 and functional residual capacity (FRC) leading to the small airway collapse, mismatch of ventilation to perfusion and hypoxia (13, 14).

The chest expansion is related to the lung volume and respiratory muscles (15). The factors influent the chest expansion are the suitable lengthening of respiratory muscles and soft tissue flexibility. The tightness of the soft tissue around the chest wall can limit the chest expansion (16). In the case of patients undergoing lung resection, adhesion will be formed in the healing process of the surgical wound. The adhesion also affects the tissue flexibility, which is a cause of the limitation of the chest expansion found in these patients.

The chest expansion in patients undergoing postoperative pulmonary resection is also limited by rib cage stiffness and soreness (17). The presence of ICD in patients after thoracic surgery delayed thoracic mobilization activities (18). After thoracic surgery, the motion on the operated side of the thorax was significantly reduced and the degree of asynchrony between the thorax and abdomen was significantly increased. A change of respiratory system biomechanics during quiet breathing resulted from thoraco-abdominal asynchrony would decrease the motion of the thorax and decrease chest expansion and ventilation in these patients (19).

A meta-analysis reported that patients without PPCs after lung resection had significantly higher exercise capacity than patients with PPCs (20). After lung resection, exercise capacity seems to be decreased because of the ventilatory limitation. The wound adhesion from the healing process limits the mobility of the chest wall and causes ventilatory limitation (21).

The conventional physical therapy program could reduce PPCs, LOS, morbidity, mortality, and healthcare cost in thoracic surgery. The program encompasses preoperative and postoperative treatments including education, breathing exercise,

airway clearance, ambulation, exercise training, and pulmonary rehabilitation (2, 18, 21, 22).

Chest mobilization technique is the part of an exercise for increasing chest expansion and improving ventilation. It is performed by moving arms up as far as possible combined with inhaling appropriately. The chest mobilization technique affects to open individual rib cage of the upper, middle, and lower parts of the chest wall and also increases the mobility of sternocostal and costovertebral joints, which will improve chest movement and ventilation. Thus, this technique could help patients who had a limitation of chest mobility in increasing chest expansion and promoting ventilation (16, 17). The chest mobilization technique has been reported that it could increase the chest expansion in healthy adults (23), low back pain (24), stroke (25), and chronic obstructive pulmonary disease (COPD) patients (26-28). The other benefits of this technique are improving forced vital capacity (FVC) in chronic low back pain patients (24), reducing dyspnea, improving expired tidal volume (V_T), increasing oxygenation in COPD patients (27, 29) and relieving pain in post thoracotomy patients (30, 31).

The main problem of the patients undergoing lung resection is the limitation of chest wall movement resulted from surgical pain, adhesion, and rib cage stiffness. The conventional physical therapy program does not resolve this problem and the usual programs may not be enough to improve ventilation in these patients. There has been a study showed that the shoulder exercise and thoracic cage mobility programs provided for the patients with thoracotomy at the postoperative period to discharge could relieve pain and improve shoulder function (30). However, the previous study has not investigated the chest mobilization technique for increasing chest expansion, reducing pain, and increasing functional capacity in patients undergoing lobectomy. Therefore, the purposes of the current study are to investigate the effect of combined chest mobilization with physical therapy treatment on chest expansion and pain in patients undergoing lobectomy and to examine the effect of the combined chest mobilization with physical therapy treatment on the functional capacity.

Research questions of this study:

Does combined chest mobilization with physical therapy treatment improve the chest expansion, reduce pain, and increase functional capacity in patients undergoing lobectomy more than the control group?

The objectives of this study:

1. To compare the effect of combined chest mobilization with physical therapy treatment on chest expansion, pain score, and functional capacity in patients undergoing lobectomy between experimental group and control group.

2. To compare the effect of combined chest mobilization with physical therapy treatment on chest expansion, pain score, and functional capacity in patients undergoing lobectomy between periods of the experimental time.

The hypothesis of this study

1. The experimental group performing combined chest mobilization with physical therapy improve chest expansion, reduce pain, and increase functional capacity more than the control group.

2. The experimental group performing combined chest mobilization with physical therapy improve chest expansion, reduce pain, and increase functional capacity after a period of the experimental time.

The benefit of the study

If the chest mobilization combined with physical therapy treatment can increase chest expansion, relieve pain and increase functional capacity in patients undergoing lobectomy more than the control group, this technique should be added to the treatment of these patients. The chest mobilization would be informed to the physical therapists to use this technique for improving the chest expansion, relieving pain, and improving the functional capacity of the patients undergoing lobectomy.

Definition of terms

Lobectomy is considered a removal tumor in the parenchyma at one or two lobes of the lung (1).

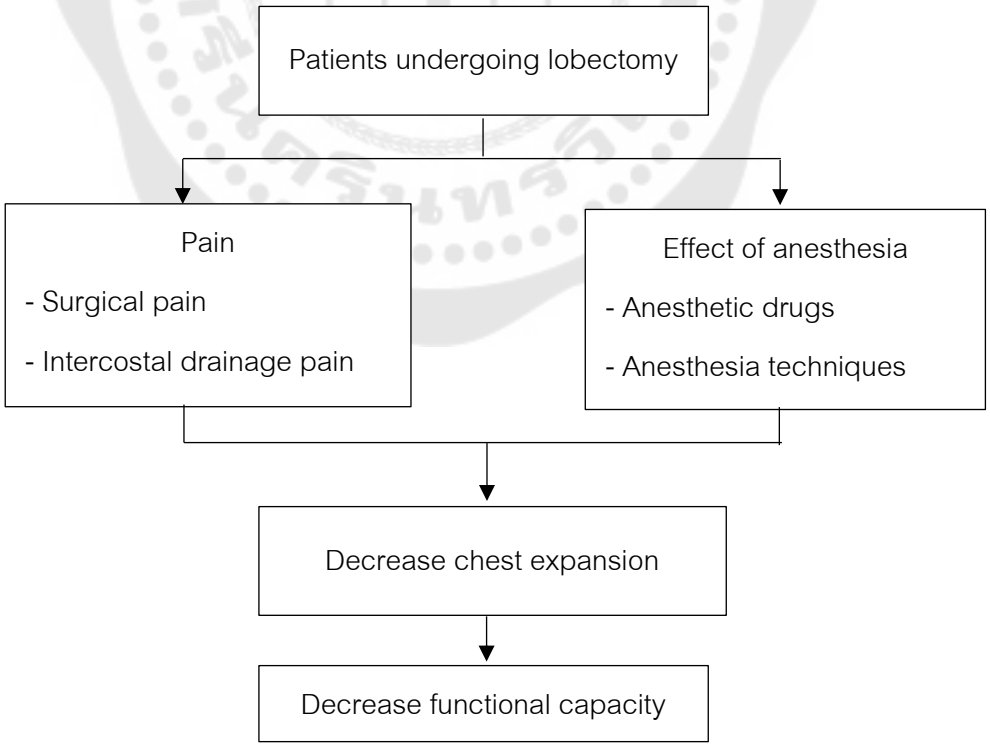
Chest mobilization is a part of breathing exercise which perform by moving arms up as far as possible with an appropriate inhalation during arm movement (12).

Chest expansion is the measurement using by cloth tape and calculated from the end of forced inspiration minus the end of forced expiration (37).

Six-minute walk test (6MWT) is the test that is performed to assess functional capacity in cardiopulmonary patients and healthy subjects following American Thoracic Society (ATS) guidelines (32).

Functional capacity is the ability to reflect the function during daily activities. The 6MWT is performed to assess functional capacity (33).

Conceptual framework



CHAPTER 2
LITERATURE REVIEW

1. Lung resection

During the period from 1999 to 2006, over 49,000 patients received lung resection. Lung resection is a technique for removing the abnormal tissue in the lung. There are several types of lung resection including wedge resection, segmentectomy, lobectomy, and pneumonectomy (1).

Approximately 18.1% of pulmonary surgical management in primary lung cancer is wedge resection. Wedge resection is the technique to remove only the area of tumor from the lung and it reduces less lung volume than other types of lung resection. Segmentectomy will remove tumor surrounding lung parenchyma. It is an anatomical segment resection and may include the dissection of lymph nodes. Lobectomy is considered a removal tumor in the parenchyma at one or two lobes of the lung. The lobectomy technique has been shown the most common surgical method for patients undergoing lung resection with up to 66% of all lung resection. Pneumonectomy is considered a removal tumor involving the total of one lung and provided in the lowest rate of lung resection (1). This technique cause to lose lung volume and decrease FEV_1 more than other types of lung resection (10).

The surgical techniques in lung resection consist of thoracotomy (approximately 70%), VATS (approximately 28%), and other techniques (approximately 2%) (1). VATS is increasingly used for lung resection and has been shown to less aggravation of pain, faster recovery respiratory function, and staying in a shorter time in the hospital than thoracotomy (2). However, the study by Brocki et al. found that surgical procedures i.e. VATS or thoracotomy were not correlated with the maximal inspiratory pressure (MIP) and the incidence of PPCs (3).

2. Postoperative pulmonary complications

Postoperative pulmonary complications (PPCs) are commonly found in post lung resection including respiratory failure, acute respiratory distress syndrome (ARDS), prolong mechanical ventilator or reintubation after surgery, pneumonia, atelectasis, myocardial infarction and cardiac arrhythmia (20). PPCs are associated with the LOS, morbidity, mortality, and health care costs in the public health system. The incidence of PPCs ranges from <1% to 23% in a major surgery (4) depending on treatment setting, type of surgery, and the identifying of PPCs (4, 5, 34). Approximate 11.5% of the incidence of PPCs was found in patients undergoing thoracic and abdominal surgeries (5).

Postoperative lung resection affected to reduce lung volumes such as expiratory reserve volume (ERV), residual volume (RV), vital capacity (VC), total lung capacity (TLC) (6, 7), FVC, diffusing capacity (D_L) and exercise capacity (8). The postoperative FEV_1 is the most common predictor of co-morbidity and PPCs. It indicates the risk of developing PPCs in patients undergoing lung resection (9). The high lung volume resection affects the reduction of FEV_1 more than the lower lung resection, for example, the pneumonectomy reduces FEV_1 more than the wedge resection or the lobectomy (8, 10).

After lung resection, the intercostal drainage (ICD) is usually presented for removing leaked air and fluid in the pleural cavity. Refai et al. demonstrated that the patients being on ICD had experienced more pain than the ones from which removing the ICD. At the pre-removal of ICD, the static pain score was 2.6, dynamic pain score was 4.1 and the average FEV_1 was 53% predicted value. After the chest tube removal, both static and dynamic pain scores were significantly decreased by 42% and 41% and significantly increased average FEV_1 value by 13% in patients undergoing lung resection either VATS or thoracotomy. Thus, the chest tube influence on pain and limit respiratory function in these patients (11).

Normally, the lung volume is generated by the respiratory muscles, which consists of the inspiratory and expiratory muscles (12). In the lung resection patients,

the respiratory muscle will be impaired because of the muscle relaxant drug used during operation and causes the loss of muscle tone. The respiratory muscle dysfunction found after the operation will decrease in the minute ventilation (V_E) as a result of decreased respiratory rate (RR) or tidal volume (V_T) or both. Changing in V_E causing reduces FEV_1 and FRC leading to the small airway collapse and increase in pulmonary shunt (13, 14). Increase pulmonary shunt in the respiratory system leads to a mismatch of ventilation to perfusion, which also affecting to hypoxia. Besides, a change in position from an upright position to supine causes the falling of FRC due to upward pressure from abdominal contents and more cephalad position of the diaphragm. However, the 30° head-up position could help to increase FRC after anesthesia (14).

Anesthesia during operation effects to impair mucociliary function, decreases respiratory frequency beat, and increases the amount of mucus. Muscle relaxant drug is commonly used during the surgical process, causes to relax the upper airway muscle tone contributed to a loss of cough reflex and secretion accumulation, which affected lung infection and atelectasis. Moreover, decreasing physical activity after surgery causes declining mucous clearance, resulting in respiratory complications such as atelectasis and pneumonia. Therefore, the increase of airway obstruction and airway resistance of the respiratory system is commonly found in postoperative patients (14).

Normally, the chest expansion is related to respiratory muscle strength and lung volume. The higher lung volume is generated by the higher respiratory muscle strength which resulted in larger chest wall movement (15). The suitable length of respiratory muscles and soft tissue flexibility is correlated to lung volume. The tightness of the soft tissue around the chest wall could limit the chest expansion (16). In patients undergoing lung resection, the surgical wound which is in the healing process will produce adhesion. The adhesion also limits the tissue flexibility, which is a cause of the reduction of chest expansion.

The chest expansion in the patients undergoing lung resection was also limited by rib cage soreness (17). The surgical pain affects respiratory function, chest wall mobility, and ventilation. The shortness of breathing is the most common found in

patients undergoing lung resection due to surgical pain and there was affected to decrease chest expansion. The change of breathing pattern after surgery will reduce the ventilation. A survey in Australia and New Zealand found that the presence of the intercostal chest drains delayed the shoulder and thoracic mobilization activity in a patient undergoing thoracic surgery (18). The delayed of the shoulder and thoracic mobilization activity causes more limitation of chest wall mobility and ventilation in patients after operation.

Recently, Elshafie et al. investigated chest wall motion in patients undergoing lung resection using plethysmography. They found that the chest wall motion was significantly decreased on the operated side. After lobectomy, the chest wall motion moved asynchrony between right-left hemi-thorax and thoraco-abdominal region. Thoraco-abdominal asynchrony has been reported to increase the change of respiratory system biomechanics during quiet breathing. The thoraco-abdominal asynchrony was assumed the insufficient thoracic mobility around the sternum. Furthermore, the thoraco-abdominal asynchrony has been shown to predict poor functional ability (19).

A meta-analysis found that patients undergoing lung resection without PPCs related to higher maximal oxygen consumption (VO_2 max) than patients with PPCs. They suggested that the VO_2 max is a useful parameter for predicting PPCs (20). Decreasing in functional ability and exercise capacity seems to be a consequence of ventilatory limitation after lung resection. The wound adhesion from the healing also limits the mobility of the chest wall and causes ventilatory limitation (21).

3. Physical therapy for lung resection

A recent review reported that the physical therapy management could reduce PPCs, length of hospital stay, morbidity, mortality, and health care cost. The physical therapy management in pulmonary surgery encompasses preoperative and postoperative treatments. The preoperative programs include inspiratory muscle training, airway clearance, pulmonary rehabilitation, and preoperative education (22). The postoperative physical therapy management focuses on airway clearance,

promoting chest expansion and ventilation, maintaining range of motion of shoulder level, early mobilization, early ambulation, and pulmonary rehabilitation program (2, 18, 21, 22).

Airway clearance techniques including postural drainage, percussion, vibration, cough, forced expiration technique, active cycle of breathing technique, endotracheal suction, and early mobilization are the most common treatments providing in patients undergoing thoracic surgery (2, 18, 35). Treatment of the secretion accumulation helps to re-expand the alveolar collapse and decrease lung infection and atelectasis. Deep breathing exercise provides alveolar recruitment and helps the secretion clearance, which enhances airway widen and improves expiratory force (21).

Physical therapy treatment which is a deep breathing exercise, sustained maximal inspiration (SMI), incentive spirometry (IS), intermittent positive pressure breathing (IPPB), positive expiration pressure (PEP), bi-level positive airway pressure (Bi-PAP) have been reported to improve lung expansion (2, 12, 18, 35). However, America Association for Respiratory Care's (AARC) guideline did not suggest incentive spirometry as a routine to prevent postoperative pulmonary complications and atelectasis in upper abdominal surgery and coronary artery bypass graft patients. The guideline also addressed that the deep breathing exercise promoted the same benefit as incentive spirometry. It recommends that the incentive spirometry must be used with deep breathing techniques, direct cough, and early mobilization for preventing PPCs (36).

Early mobilization and early ambulation promote airway clearance and reduce PPCs (37). Reeve et al. found that respiratory physiotherapy interventions composing of deep breathing, coughing, and exercise programs when compared with early mobilization did not show any significant difference in reducing the incidence of PPCs and LOS in patients after thoracotomy. The study suggested that the airway clearance technique should not routinely provide for the post thoracotomy (38).

The causes of the limitation of chest wall movement and insufficiency of lung expansion are from many factors including surgical pain, adhesion, and rib cage

stiffness after lung resection. According to conventional physical therapy management, it may not resolve the problem and may not be sufficient for increasing soft tissue flexibility and reducing rib cage stiffness in these patients. The chest mobilization has been proposed to increase rib movement and chest excursion, may help facilitate thoracic expansion and ventilation (17). Therefore, combining the chest mobilization with conventional physical therapy may improve chest expansion and ventilation and provide more benefits to lung resection patients.

4. Chest mobilization technique

Chest wall mobility is related to respiratory muscle strength (maximum inspiratory pressure and maximum expiratory pressure) and lung volumes. Lung function which is correlated to the chest wall mobility is FVC, FEV_1, the inspiratory capacity (IC), and expiratory reserve volume (ERV). The larger chest wall mobility is related to the higher lung volume which is generated by the greater respiratory muscle strength. However, several factors affected the lung volumes including the elastic recoil, compliance of the lung, and the resistance of the airway (15).

Chest mobilization technique performs by moving arms up as far as possible with an appropriate inhalation during arm movement. It affects opening the individual rib cage and maximize the chest wall mobility which promoting ventilation for those having abnormal chest mobility. Each position of chest mobilization could stretch the chest wall and promote ventilation strategies. For example, in the supine position and placing a roll of a towel under the thoracic spine, the gravity will pull the shoulder back to the bed and allow the anterior chest mobility. This position opens the anterior chest and stretches the intercostal and pectoralis muscles, which will facilitate upper chest expansion. In the lateral chest mobilization, the position set in the side-lying with a roll of towel or pillow under the weight-bearing side, it promotes to mobilize the lateral chest wall (12, 16, 17).

The chest mobilization technique provides different purposes when performing in different regions of the chest wall. The anteroposterior chest wall mobilization is used to improve ventilation at both upper lobes, the posterolateral chest wall mobilization

improved ventilation at the lower lobe regions, and the lateral chest wall mobilization improved ventilation of the lower part of the lungs. The ventilation is improved because the tissue around the rib is stretched, the respiratory muscles are in the suitable length which leading to improve chest wall flexibility and mobility. For this reason, the chest mobilization technique should be possible to facilitate chest expansion and ventilation for those with chest wall stiffness especially after lung resection (16).

The chest mobilization technique does not affect only the rib and tissue flexibility but also improves joint mobility including sternocostal and costovertebral joints. During trunk flexion, the costovertebral joint moves anterior sagittal rotation and gliding. In contrast, the costovertebral joint moves downward rotation and gliding during extension. In the lateral flexion, the costovertebral joint moves slight rotation and opens the rib cage resulting in increasing of rib space of the thorax. In the trunk rotation, the rib moves rotation with costotransverse posterior gliding and the thoracic body is elevated and depressed in each segment (16). Thus, this technique is an improvement in the mobility of the surrounding chest wall which improves chest expansion and promotes ventilation.

The chest mobilization technique can be applied in patients with limitations of chest wall movement i.e., scoliosis, kyphosis, ankylosing spondylitis, spinal cord injury, scleroderma, multiple sclerosis, prolonged use of a mechanical ventilator, chronic lung disease, pneumonia and post pulmonary surgery patients. The contraindications for this technique include the conditions of severe or unstable rib fracture, metastasis bone cancer, tuberculosis spondylitis, severe osteoporosis, herniation, severe pain, and unstable vital signs (16).

There are several studies investigated the chest mobilization technique and found that it could increase chest expansion in healthy adults (23), low back pain (24), stroke (25), and chronic obstructive pulmonary disease (COPD) patients (26-28). Moreover, several studies have been evaluated the efficacy of chest mobilization not only chest wall expansion but also other benefits, for example, the increase in oxygenation, relieve pain, and improve the lung volume.

The study in healthy adults investigated the effect of chest mobilization and found that the self-mobilization of the thoracic region three times per week for six weeks could increase chest expansion (23). The addition of thoracic mobilization to physical therapy program improved chest wall expansion, FVC, MIP, and reduced disability in low back pain patients (24). The stroke patients, performing chest mobilization exercise 30 minutes per session, three times per week for four weeks showed a significant increase in chest expansion when compared to core stabilization exercise group (25). The studies in COPD patients demonstrated that oxygen saturation, tidal volume, expiratory time were improved after training with chest mobilization (26, 28, 29) and the addition of chest wall stretching exercise to physical therapy program in COPD patients with unable weaning off ventilator could increase chest expansion, improved expired tidal volume and reduced dyspnea (27). Besides, the studies in thoracic surgery including pulmonary surgery and coronary artery bypass graft patients showed that the thoracic cage mobility program providing during the period of postoperative to discharge could improve shoulder function (30) and relieve pain (30, 31).

5. Outcomes

5.1 Chest expansion

The chest expansion measured with cloth tape is widely used in clinical practice because it is simple and easy to detect chest movement. The cloth tape measure correlated with lung function (39, 40). It is used to evaluate chest movement and represented indirectly to the lung volume. Therefore, cloth tape measurement should be appropriated to detect chest expansion which will reflect the volume of the lungs in patients undergoing lung resection.

Participants are instructed to perform a maximum inhalation and exhalation. The chest expansion is calculated from the thoracic circumference at the end of forced inspiration minus thoracic circumference at the end of forced expiration (39). The reliability of the technique is high with the intraclass correlation coefficient of 0.81-0.95 when measuring in healthy subjects (39-41), COPD patients (42), and ankylosing spondylitis patients (43).

In several studies, chest expansion was measured by the thoracic circumference technique. Chest expansion can be performed in standing and sitting positions. The two different levels of the thoracic region, the upper and lower part, are commonly used. The anatomical marks for the upper part of the lungs are the third intercostal at the clavicular line and level of the 5^{th} thoracic spinous process. The anatomical marks for the lower part are the xiphoid process and level of the 10^{th} thoracic spinous process (39). Before measuring, the examiner will pull the end of the tape away from the subject body and keep the cloth tape flat against the subject skin. The instruction for chest expansion measurement should be "breathe in maximally and make yourself as big as possible" and "breathe out maximally and make yourself as small as possible". The examiner will measure chest expansion at peak inhalation and peak exhalation three times for each participant. The best value in three times of measurement will be considered (44).

The recent study found asynchronous of the chest wall between operated and non-operated side and the chest expansion was significantly decreased in the operated side in patients undergoing lobectomy (19). Therefore, the chest expansion measured by the thoracic circumference technique may not be appropriated to detect chest expansion in these patients. Hemi-thorax technique measurement will be reasonable to detect chest expansion more than the thoracic circumference technique in lobectomy patients.

There has been no report of the reference values and the minimal change of the hemi-thoracic chest expansion. For the thoracic circumference technique of chest expansion, the previous study reported that the mean difference change in thoracic expansion in the healthy subject should be more than 0.6 centimeters (cm) (39). However, the study in asthma patients had been reported the mean changes of thoracic expansion is 0.9 cm. at the upper thoracic level and 0.8 cm. at the lower thoracic level (45).

5.2 Pain score

The numeric rating scale is commonly used for evaluating pain perception. The number selected by the participant reflects pain intensity which 0 equal no pain and 10 equal the worst pain. Numeric pain has been used in patients undergoing thoracotomy to detect pain intensity (30).

The reliability of the numeric scale is moderate to high with an intraclass correlation coefficient of 0.67–0.82 and the validity is high as r=0.89-0.96. It is a good tool for accessing pain intensity when compared with other measurement tools such as the visual analog scale, face pain scale, and verbal descriptor scale (46).

5.3 Functional capacity

Functional capacity is the ability to reflect function during daily activities (33). Several tests are available for the evaluation of functional capacity in patients undergoing lobectomy, including the cardiopulmonary exercise test, shuttle walk test (47), and six-minute walk test (6MWT) (32).

The cardiopulmonary exercise test is the gold standard but it is more expensive, used complex technology, and required advance trained physicians than other tests (48). The shuttle walk test distance demonstrated a significant correlation with peak VO_2 in the cardiopulmonary exercise test (47). However, this test is required for some technology and trained clinician. The 6MWT is easy to perform, does not need close medical supervision and it is closely relevant to daily activities ordinarily (33).

The 6MWT was a good correlation (correlation coefficients = 0.4-0.93) with the peak VO_2 in the cardiopulmonary exercise test (48-50), weak to moderate relationships with FEV1, FVC, and DLCO with intraclass correlation coefficients of 0.31–0.55. The 6MWT showed high reliability in people with chronic respiratory disease, with excellent intraclass correlation coefficients of 0.82–0.99 (50).

6MWT is the most common measurement of functional capacity in a clinical setting because it is simple, safe, use 100 feet hallway and does not need any complex tools or advance trained physician. The 6MWT can evaluate response during the exercise of all the systems including the cardiovascular system, pulmonary system,

systemic circulation, peripheral circulation, blood, neuromuscular unit, and muscle metabolism (32).

6MWT is useful for comparing treatment, assessing the functional status and predicting morbidity and mortality in patients undergoing pulmonary and cardiac surgery, COPD, pulmonary hypertension, heart failure, other chronic lung diseases, musculoskeletal patients and older patients. The precaution and contraindication for 6MWT are unstable angina, resting heart rate more than 120 beats per minute, resting systolic blood pressure more than 180 mmHg, and diastolic blood pressure more than 100 mmHg. (32).

The six-minute walk distance (6MWD) was a maximum distance measured in six minutes. The subjects must walk as far as possible in six minutes in a hard hallway. The previous study showed the minimal clinical significant difference (MCID) of 6MWD is 54 meters (m.) (32). However, the recent study suggested the MCID of 6MWD is 25-33 m. (50).

In the process of 6MWT, the participants should sit in a chair at least ten minutes before the test and measure blood pressure, heart rate, oxygen saturation, and Borg scale. Then, participants move to the starting point and perform the instruction of the test. The participants start to walk, the examiner starts the timer and keep the tone of the voice when using standard phrases of encouragement. After the test, the examiner record the distance, blood pressure, heart rate, oxygen saturation and Borg scale (32).

CHAPTER 3
METHODOLOGY

1. Research design

This study was designed as a randomized controlled trial with single-blind (outcome assessor blinding) and was registered in Thai Clinical Trails Registry which was TCTR20190221001.

2. Ethical consideration

This study was submitted to the ethics committee of the Central Chest Institute of Thailand for ethics approval which was 072/2562 (APPENDIX A&B).

3. Participants

The participants were recruited from the Central Chest Institute of Thailand. The inclusion criteria were as follow:

1. Age $\geq$ 18 years old
2. Elective pulmonary resection at Central Chest Institute of Thailand
3. Undergoing lobectomy via thoracotomy or VATS

The exclusion criteria were as follow:

1. Unable to participation
2. Limitation of shoulder range of motion
3. Hemoptysis
4. Received respiratory physiotherapy within 2 weeks before surgery
5. Hemodynamic instability within the first day post operation
6. On mechanical ventilator more than 24 hours after surgery
7. The postoperative complication of chylothorax and severe air leak (prolong air leak during inspiration and expiration)
8. Comorbidity following post-cardiac surgery, COPD and restriction lung disease such as interstitial pulmonary disease, scoliosis

4. Research setting

This study was set in the pulmonary surgery ward at the Central Chest Institute of Thailand, Nonthaburi, Thailand.

5. Sample size calculation

G Power program version 3.1 was used to calculate the sample size in this study. Independent sample t-test with the difference between two independent means was used to calculate with an expected statistical power of 0.8, alpha error probability of 0.05 and effect size of 0.86 (the chest expansion of the control group: 2.80 $\pm$ 1.10 cm. and the experimental group: 3.73 $\pm$ 1.07 cm.) based on the study of Parmar et al. (28). The determining sample size for this study was 36 participants.

6. Sampling techniques

The sampling technique was used by a purposive technique. The participants were randomized by computerized generation (www.randomizer.org) and parallel allocated into two groups including the control group and experimental group with seal opaque envelop in a consecutively numbered. The randomization was allocated by an assistant researcher who did not involve in the treatment or outcome assessing. The randomization process was conducted before recruiting subjects.

7. Variables

Independent variable: chest mobilization program

Dependent variable: chest expansion, pain score, 6MWD

Control variable: standard physical therapy treatment

8. Outcomes

Primary outcome: chest expansion, pain score

Secondary outcome: 6MWD

9. Material and research tools

Chest expansion was assessed using a measuring tape with centimeter markings (Hoechstmass®, Germany) . The numeric scale was used to rate the pain score. 6MWT was used to assess the functional capacity and measured in its distance (6MWD). Participants were measured heart rate using Polar® heart rate, blood pressure using sphygmomanometer, oxygen saturation using pulse oximetry and dyspnea score using a modified Borg scale. The 30 meters hallway, two small cones to mark the turnaround point, stopwatch and a chair were used for 6MWT. LOS was recorded on the discharge day.

10. Experimental procedure

The elective participants for lobectomy in the Central Chest Institute of Thailand were recruited. Participants were explained about the objectives and procedures of the study. If they agree to participate, they had to sign a consent form. Then, the participants were randomly assigned to two groups, control and experimental groups. This process was conducted by an assistant researcher who did not involve in the outcome measurement or treatment.

Control group: the participants received physical therapy treatment once a day.

Experimental group: the participants received physical therapy treatment same as the control group combined with active chest mobilization

The outcome assessor, who was blinded the group allocation, measured all outcomes at preoperative and the first to third postoperative day. All of the outcomes were measured after the participants receiving physical therapy treatment and performing the first session of chest mobilization in the morning of each day. All participants received the treatment at least 3 days after the operation. The participants who received the treatment of less than 3 days was excluded from the study.

11. Physical therapy treatment

All participants received the same physical therapy treatment once a day at the pre and post-operation period from an experienced physiotherapist. The physiotherapist

provided the treatment to the control group and the experimental group followed the allocation. The outcome accessor was blinded to the groups and therapist assignment. The detail of physical therapy treatments was as follow:

Day 1 Deep breathing exercise, cough training, upright sitting, standing and shoulder range of motion exercise including shoulder flexion and abduction. If participants had a problem with secretion accumulation, postural drainage was provided, they were encouraged to walk about 10-50 m.

Day 2 Same as day 1 and increased the walking distance to 50-200 m. or as tolerance.

Day 3 Same as day 2 and increased the walking distance to 100-300 m. or as tolerance. If the patients were taken off the ICD, they were received up-down stair 1 or 2 flight and plan for discharge.

Nowadays, most of the patients were discharged from the third postoperative day which depending on their conditions. If the patients did not discharge on the third postoperative day, they would continue to receive physical therapy treatment to discharge day. If the participants had any postoperative complications, the complications were recorded.

12. Chest mobilization technique

The participants in the experimental group received physical therapy treatment same as the control group combined with two active chest mobilization as shown in Figure 1 to Figure 9. The chest mobilization was performed for five times per set, three sets per session and three sessions per day. The participants performed the chest mobilization by themselves and under physiotherapist supervision on the first time.

All participants received a booklet within the first postoperative day. They had to record the number and the session of chest mobilization that they performed each day. If the patients did not discharge on the third postoperative day, the patients continued to perform chest mobilization after the third postoperative day until discharge.

The active chest mobilization was as follow:

Day 1 Position 1: Lying on their back, take both hands back of the neck then raise elbows and spread elbows out as far as possible with deeply and slowly inhale. After that, slowly exhale and move elbows up and the hands are still behind the neck.

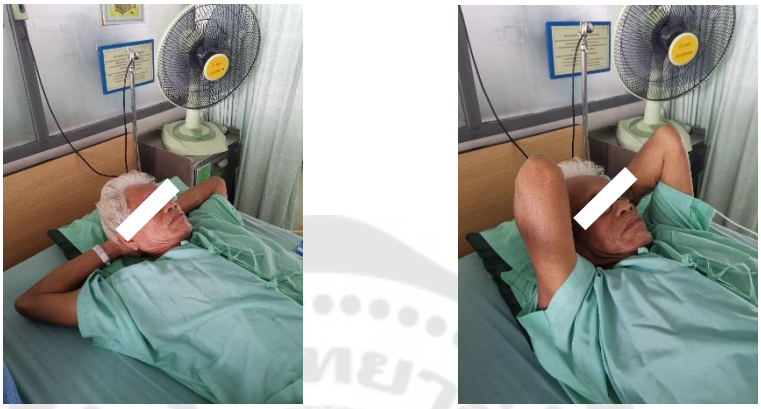


Figure 1 Lying position with chest mobilization

Position 2: Side-lying with the operated side on top, take a hand back of the neck then raise the arm as possible with deeply and slowly inhale. After that, slowly exhale and move the arm down and the hands are still behind your neck.

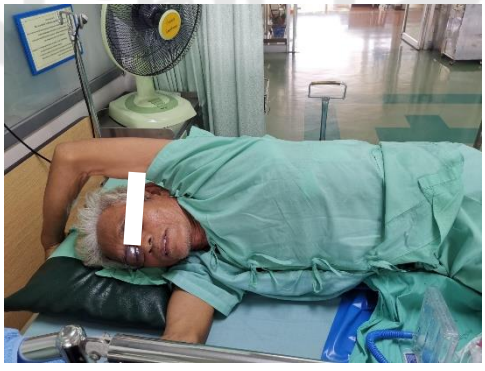


Figure 2 Side-lying with chest mobilization

Day 2 Position 1: Upright sitting, take both hands back of the neck then raise elbows and spread elbows out as far as possible with deeply and slowly inhale. After that, slowly exhale and move elbows forward and the hands are still behind the neck.

Figure 3 Sit with chest mobilization for the anterior part

Position 2: Upright sitting position, take both hands back of the neck and raise elbows and spread elbows out with exhalation then move the elbows forward with deeply and slowly inhale and the hands are still behind the neck.

Figure 4 Sit with chest mobilization for the posterior part

Day 3 Position 1: Side-lying with the operated side on top with roll tower or pillow under the thoracic region. Take the hand back of the neck then raise the arm as possible with deeply and slowly inhale. After that, slowly exhale and move the arm down and the hands are still behind the neck.

Figure 5 Side-lying with pillow or roll tower with chest mobilization

Position 2: Upright sitting and take the hands of both sides back of the neck then bend the trunk to another non-operated side as far as possible with taking deeply and slowly inhale. After that, slowly exhale and back to the start position

Figure 6 Sit and bend the trunk to non-operated side with chest mobilization

Day 4 Position1 and 2: Upright sitting and fold one's arms across the chest, slowly twist and turn as far as possible with taking deeply and slowly inhale. After that, slowly exhale and back to the start position and repeat with another side

Figure 7 Sit and twist the body with chest mobilization

Day 5 Position 1: Upright sitting and take the arms in front of the body, move arms up and spread the arms, and open the chest as far as possible with taking deeply and slowly inhale. After that, slowly exhale and back to the start position.

Position 2: Upright sitting with spread the arm over the head with exhalation after that take their arm down with slowly inhale

Figure 8 Sit and the arm in front of the body with chest mobilization

Day 6 Position1: Standing with the arms in front of the body and put the hands against the wall. Then, bend the arms and move the body forward with inhalation. After that, push the hands against the wall with exhalation.

Position 2: Standing with the arms in front of the body and put the hands against the wall. Then, bend the arms and move the body forward with exhalation. After that, push the hands against the wall with inhalation.

Figure 9 Stand with chest mobilization

13. Outcome measures

The primary outcomes (chest expansion and pain score) were measured at preoperative day and the first to the third postoperative day. The secondary outcome (6MWD) was measured on preoperative day and discharge day.

13.1 Primary outcome

13.1.1 Chest expansion

Chest expansion was measured in a sitting position using a cloth tape at two different levels of the thoracic region, upper and lower part. The hemi-thorax technique was used to measure chest expansion in the operative and non-operative side. For the upper part of the thoracic expansion, the anterior anatomical mark was at the third intercostal from the clavicular line and passed to the mid sternum and the posterior anatomical mark was at the level of the fifth thoracic spinous process. The

lower part of the thoracic expansion, the anatomical marks were at the xiphoid process and the level of the tenth thoracic spinous process.

The procedure of hemi-thorax chest expansion measurement was designed. An assessor fixed the tape measurement at the anterior anatomical marker and another assessor pulled the end of the tape away from subjects' bodies to the posterior maker and keep the cloth tape flat against the subjects' skin. The assessor measured chest expansion at the peak inhalation and peak exhalation for three times in each level. The instruction for chest expansion measurement was "breathe in maximally and make yourself as big as possible" and "breathe out maximally and make yourself as small as possible". The chest expansion was calculated from the end of maximum inspiration minus the end of maximum expiration (44). The maximum value of the three chest expansion measurement was selected and recorded. As there have not been reported the hemi-thorax chest expansion measurement, the intra-rater reliability was conducted in healthy subjects before measuring in the patients.

13.1.2 Pain score

Pain perception of the surgical wound was evaluated from the patients using a numeric rating scale. The numeric rating scale is the most commonly used in pain assessment in clinical practice. The participants selected the number reflected pain intensity which 0 equals no pain and 10 equal the worst pain (46).

13.2 Secondary outcome

13.2.1 Six-minute walk distance

6MWT was performed according to the American Thoracic Society (ATS) guideline (32). Participants should rest in sitting on a chair about 10 minutes before the test. The examiner measured pulse rate using a Polar heart rate, peripheral oxygenation using a pulse oximeter, and dyspnea score using a modified Borg scale. The participants should walk as far as possible in a 30-meter hard corridor and turn around the cone at the starting and the end of the hallway for 6 minutes. The instructions were given to the participants following the ATS guideline. The participants stopped walking

when they complete 6 minutes of walking and the examiner recorded the walking distance (32). The 6MWD was measured at preoperative day and on discharge day.

14. Data analysis

The data analysis was performed with SPSS (SPSS Inc., Chicago, IL, USA) version 22 for windows. Analyses were conducted on an intention-to-treat, using all available data from randomized participants. Normal distributions of all data were assessed using Shapiro-Wilk. Chi-square test was used to compare the number of genders and dichotomous data between groups. Independent sample t-test was used to compare the general characteristic data and lengths of hospital stay between groups. Two-way mixed ANOVA protected by Greenhouse-Geisser correction for non-normal data was used to compare the main effect of all outcome measures between preoperative day and the 1^{st} to the 3^{rd} postoperative day, within a group and between groups. Pair-wise multiple comparisons were made using Bonferroni. Significant difference was set at $p<0.05$.

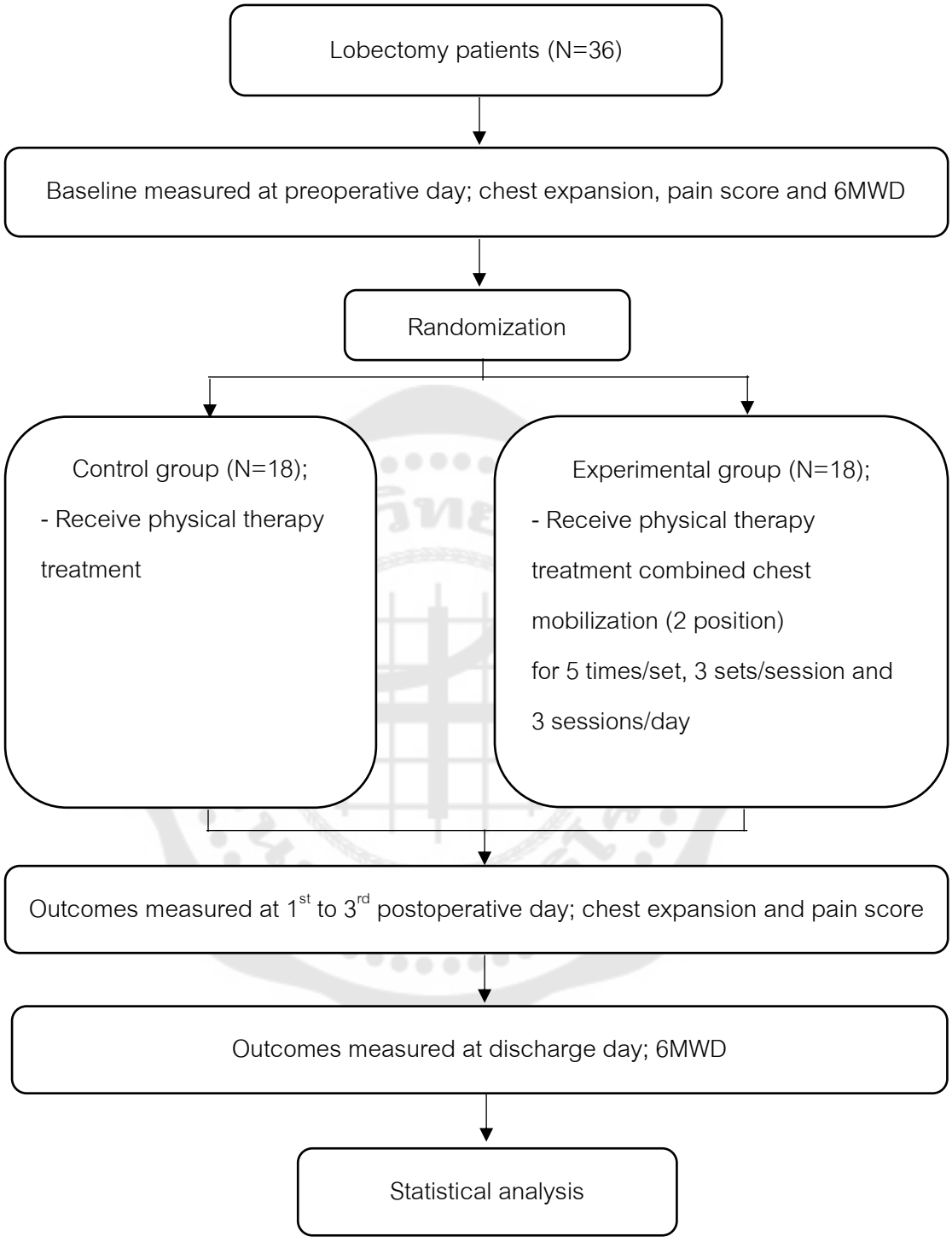


Figure 10 Flow chart of this study

CHAPTER 4
RESULTS

Before conducting the main experiment, the intra-rater reliability (ICC) of the hemi-thorax chest expansion measurement was performed. Ten healthy subjects were recruited. The ICCs (3, 1) of the upper chest expansion for the left and the right sides were 0.92 and 0.98, respectively. The ICCs (3, 1) of the lower chest expansion of the left and the right sides were 0.93 and 0.91, respectively. This results showed an excellent intra-rater reliability of hemi-thorax chest expansion (51). The standard error of measurement ranges from 0.04 to 0.09 cm. for upper chest and range from 0.11 to 0.12 cm. for lower chest. The minimal detectable change ranges from 0.16 to 0.35 cm. for upper chest and 0.43 to 0.47 cm. for lower chest, respectively. See detailed in Table 1.

Table 1 ICCs, SEMs and MDC for hemi-thorax chest expansion of upper and lower chest in healthy subjects using cloth tape measurement

Variables	$ICC_{3,1}$	95% CI (Lower-Upper bound)	SEM	MDC_{95}
Left upper chest	0.92	0.71-0.98	0.09	0.35
Right upper chest	0.98	0.73- 0.98	0.04	0.16
Left lower chest	0.93	0.75- 0.98	0.11	0.43
Right lower chest	0.91	0.67-0.98	0.12	0.47

ICCs: intraclass correlation coefficients, SEMs: standard error of measurement, CI: confidence interval, MDC: minimal detectable change

1. Flow of participants through the trial

The results of the RCT, Seventy-six participants who were elected to undergo lobectomy between March and December 2019 were invited to participate in this study and underwent screening for the research inclusion criteria. Forty participants were excluded because of denial to participate in this study (n=3), severe air leak after surgery (n=1), shoulder range of motion limitation (n=3), hemoptysis (n=5), receiving respiratory physiotherapy before surgery (n=1), COPD (n=3), restriction lung disease (n=2), scoliosis (n=2), vital sign instability (n=3) and receiving other surgeries including lung biopsy, segmentectomy, bleb excision, rib resection and redo-thoracotomy (n=17). Thirty-six participants were successfully randomized into two groups, with 18 participants in the control group and 18 participants in the experimental group (Figure 11). The numbers of females in the control and experimental groups were 14 (77.78 %) and 13 (72.22 %), respectively. The general characteristics and pulmonary function data of the participants are shown in Table 2. No statistical differences in general characteristics and pulmonary function data were noted between control and experimental groups in the baseline ($P>0.05$) . The comorbidities found in the participants were hypertension, dyslipidemia, diabetes mellitus, and coronary artery disease. The surgical procedures were VATS, mini-thoracotomy, thoracotomy, and mini-thoracotomy with VATS. The site of lobectomy consists of left or right upper lobes, left or right lower lobes, right middle lobe, and bi-lobectomies. The comorbidities and surgical procedures are shown in Table 3.

The mean length of intercostal drainage in control and experimental groups were 5 ± 3 days (range 2-13 days) and 6 ± 4 days (range 3-18 days), respectively. The mean length of hospital stay was 6 ± 3 (range 3-14 days) days in the control group and was 8 ± 5 days (range 4-21 days) in the experimental group. The complications after lobectomy in this study were pneumothorax, pleural effusion, upper airway obstruction, and fever. The length of intercostal drainage, length of hospital stay and, complications were shown in Table 4. There was no statistically significant difference between control and experimental groups.

2. Compliance with trial method

The data in this study were analyzed on the intention-to-treat principles. As no participants were changing the groups or drop out to the study, all 18 participants in each group were analyzed from the preoperative to the third postoperative day. The interventions were provided to the experimental group as scheduled on 100% of occasions of the trial and exercise booklets were completed by 94% of the 18 participants in the experimental group. Design and flow of participants through the trial are shown in Figure 11.

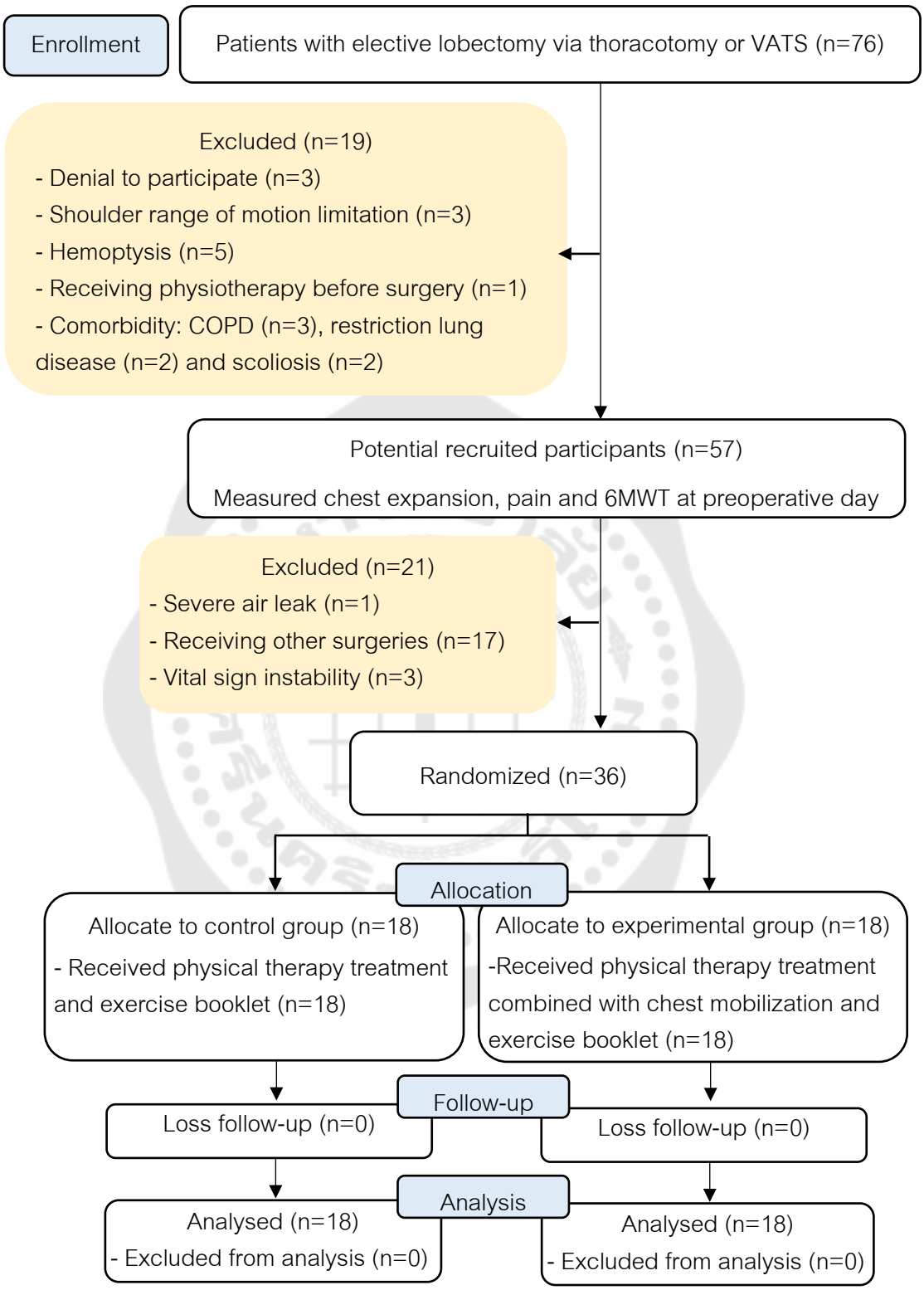


Figure 11 Design and flow of participants through the trial

Table 2 Baseline characteristics of all participants

Variable	Control group (n=18)	Experimental group (n=18)	P-value
Female, n (%)	14 (77.78)	13 (72.22)	0.85
Age (years)	58.44±11.50	58.56±9.67	0.98
Weight (kg)	60.40±10.48	59.39±8.22	0.75
Height (cm)	156.28±7.19	157.17±6.38	0.70
BMI (kg/m^2)	24.64±3.27	24.19±4.15	0.72
FEV_1/FVC (%)	86.72±12.07	84.28±9.77	0.51
FVC (liters)	2.50±0.53	2.71±0.65	0.29
FVC %predicted	95.06±15.87	104.94±20.03	0.11
FEV_1 (liters)	2.04±0.45	2.16±0.43	0.39
FEV_1 %predicted	95.28±17.29	104.06±17.91	0.14
$FEF_{25-75\%}$ (liters)	88.78±24.37	92.72±30.58	0.80
$FEF_{25-75\%}$ %predicted	88.78±24.37	92.72±30.58	0.67
PEF (liters)	6.19±1.88	6.59±2.07	0.54
PEF %predicted	106.61±18.92	113.28±18.78	0.29
Smoking history, n (%)	1 (5.56 %)	5 (27.78 %)	0.10
- Packs-year	20.00±0.00	22.70±9.43	0.81

Data presented as mean ± standard deviation.

SD: standard deviation, BMI: body mass index, FVC: forced vital capacity, FEV_1: forced expiratory volume in 1 second, $FEF_{25-75\%}$: forced expiratory flow rate at 25-75% of forced vital capacity, PEF: peak expiratory flow

Table 3 Distribution of comorbidities and surgical procedures

Variable	Control group (n=18)	Experimental group (n=18)	P-value
Comorbidities			
- HT (n)	2	3	
- DLP (n)	1	3	
- HT and DM (n)	1	0	
- HT and DLP (n)	5	2	
- HT, DLP and other (n)	3	2	
Total, n (%)	12 (67.70 %)	10 (55.60 %)	0.49
Surgical procedures, n (%)			
- VATs	14 (77.77 %)	13 (72.20 %)	0.85
- Thoracotomy	1 (5.56 %)	1 (5.56 %)	1.00
- Mini-thoracotomy	2 (11.11 %)	1 (5.56 %)	0.56
- Mini-thoracotomy with VATs	1 (5.56 %)	3 (16.68 %)	0.32
Site of lobectomy			
- RUL lobectomy (n)	5	-	
- RML lobectomy (n)	-	3	
- RLL lobectomy (n)	4	4	
- LUL lobectomy (n)	6	7	
- LLL lobectomy (n)	1	3	
- Bi-lobectomies (n)	2	1	

HT: Hypertension, DLP: Dyslipidemia, DM: Diabetes mellitus, VATS: Video-assisted thoracic surgery, RUL: Right upper lobe, RML: Right middle lobe, RLL: Right lower lobe, LUL: Left upper lobe, LLL: Left lower lobe

Table 4 Length of intercostal drainage, length of hospital stay and complications

Variable	Control group (n=18)	Experimental group (n=18)	P-value
Length of ICD (days)	5±3 (range 2-13)	6±4 (range 3-18)	0.90
LOS (days)	6±3 (range 3-14)	8±5 (range 4-21)	0.54
Complications			
- Pneumothorax (n)	4	3	
- Pleural effusion (n)	1	1	
- Fever after off ICD (n)	-	2	
- Upper respiratory obstruction (n)	1	-	
Total, n (%)	6 (33.33 %)	6 (33.33 %)	0.64

Data presented as mean ± standard deviation

LOS: Length of hospital stay, ICD: intercostal drainage

3. Chest expansion

The chest expansion measurement in this study including upper and lower chest expansion on the operative side and the non-operative side was compared between the control and experimental group at before and after lobectomy. At the preoperative day, the upper and lower chest expansion was not significantly different between groups ($P>0.05$) . There was no significant interaction between days and groups of all the parts of chest expansion ($P>0.05$).

The comparison of the upper and lower chest expansion between preoperative day and each postoperative day found that the chest expansion of the operated and non-operated sides were significantly decreased from the first to the third postoperative day when compared to the preoperative day in both control and experimental groups ($P<0.05$). The chest expansion of the first postoperative day was lowest and then the chest expansion was increased in the second and the third postoperative day when compared to the first postoperative day ($P<0.05$). Three days after the operation, the upper and lower chest expansion was not returned to baseline as they still showed a significant difference when compared to the preoperative day except the lower chest expansion on the non-operated sides.

There were no significant differences in the upper or lower chest expansion when compared between the control and experimental groups in all of the three postoperative days ($P>0.05$).

Table 5 Chest expansion on operated and non-operated sides and pain score in control and experimental groups in each day

Variables	Control group (n=18)				Experimental group (n=18)				Interaction effect	
	Pre-op	Day 1	Day 2	Day 3	Pre-op	Day 1	Day 2	Day 3	$F_{(3,102)}$	P-value
Upper chest (cm.)										
- Operated side	2.0±0.6	0.9±0.3[a]	1.2±0.5[a,b]	1.2±0.4[a,c]	2.2±0.5	1.1±0.4[a]	1.4±0.3[a,b]	1.5±0.5[a,c]	0.14	0.88
- Non-operated side	1.9±0.5	1.2±0.4[a]	1.6±0.6[a,b]	1.6±0.5[a,c]	2.2±0.5	1.4±0.6[a]	1.8±0.5[a,b]	1.9±0.7[a,c]	0.14	0.98
Lower chest (cm.)										
- Operated side	2.2±0.5	0.9±0.3[a]	1.1±0.4[a]	1.2±0.5[a,c]	2.5±0.7	1.2±0.6[a]	1.4±0.5[a]	1.5±0.7[a,c]	0.12	0.87
- Non-operated side	2.1±0.7	1.3±0.4[a]	1.5±0.6[a,b]	1.7±0.6[c]	2.3±0.7	1.6±0.6[a]	1.8±0.4[a,b]	2.1±0.8[c]	0.12	0.89
Pain score	0.0±0.0	5.2±1.9[a]	3.6±1.2[a,b]	2.7±1.4[a,c,d]	0.0±0.0	4.8±2.2[a]	3.7±1.9[a,b]	3.1±2.0[a,c]	0.70	0.52

Data presented as mean ± standard deviation

[a] Significant difference within group between preoperative and each postoperative day ($P<0.05$).

[b] Significant difference within group between 1st postoperative day and 2nd postoperative day ($P<0.05$).

[c] Significant difference within group between 1st postoperative day and 3rd postoperative day ($P<0.05$).

[d] Significant difference within group between 2nd postoperative day and 3rd postoperative day ($P<0.05$).

Table 6 Comparison between groups of the upper chest expansion in each experimental day

Day	Control group	Experimental group	P-value between group
Operated side			
-Preoperative day	2.0±0.6	2.2±0.5	0.14
-Postoperative day			
Day 1	0.9±0.3[a]	1.1±0.4[a]	0.07
Day 2	1.2±0.5[a,b]	1.4±0.3[a,b]	0.11
Day 3	1.2±0.4[a,c]	1.5±0.5[a,c]	0.06
Non-operated side			
-Preoperative day	1.9±0.5	2.2±0.5	0.14
-Postoperative day			
Day 1	1.2±0.4[a]	1.4±0.6[a]	0.20
Day 2	1.6±0.6[a,b]	1.8±0.5[a,b]	0.19
Day 3	1.6±0.5[a,c]	1.9±0.7[a,c]	0.17

Data presented as mean ± standard deviation (cm.)

[a] Significant difference within group between preoperative and each postoperative day ($P<0.05$).

[b] Significant difference within group between 1st and 2nd postoperative day ($P<0.05$).

[c] Significant difference within group between 1st and 3rd postoperative day ($P<0.05$).

[d] Significant difference within group between 2nd and 3rd postoperative day ($P<0.05$).

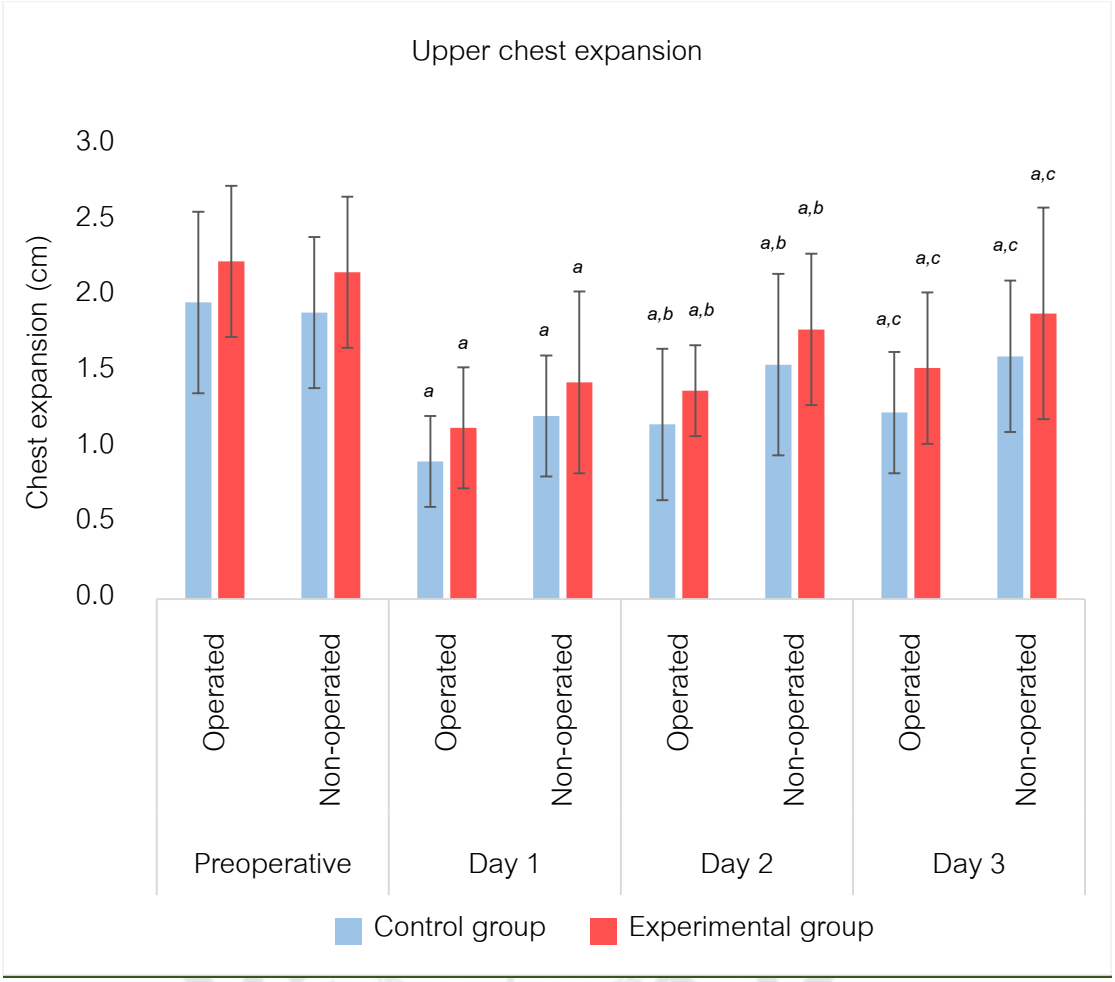


Figure 12 Comparison of upper chest expansion on operated and non-operated sides from preoperative day to the 3rd postoperative day within and between groups

[a] Significant difference within group between preoperative and in each postoperative day (P<0.05).

[b] Significant difference within group between 1st and 2nd postoperative day (P<0.05).

[c] Significant difference within group between 1st and 3rd postoperative day (P<0.05).

Table 7 Comparison between groups of the lower chest expansion in each experimental day

Day	Control group	Experimental group	P-value between group
Operated side			
-Preoperative day	2.2±0.5	2.5±0.7	0.29
-Postoperative day			
Day 1	0.9±0.3[a]	1.2±0.6[a]	0.14
Day 2	1.1±0.4[a]	1.4±0.5[a]	0.14
Day 3	1.2±0.5[a,c]	1.5±0.7[a,c]	0.14
Non-operated side			
-Preoperative day	2.1±0.7	2.3±0.7	0.31
-Postoperative day			
Day 1	1.3±0.4[a]	1.6±0.6[a]	0.08
Day 2	1.5±0.6[a,b]	1.8±0.4[a,b]	0.12
Day 3	1.7±0.6[c]	2.1±0.8[c]	0.19

Data presented as mean ± standard deviation (cm.)

[a] Significant difference within group between preoperative and each postoperative day ($P<0.05$).

[b] Significant difference within group between 1st and 2nd postoperative day ($P<0.05$).

[c] Significant difference within group between 1st and 3rd postoperative day ($P<0.05$).

[d] Significant difference within group between 2nd and 3rd postoperative day ($P<0.05$).

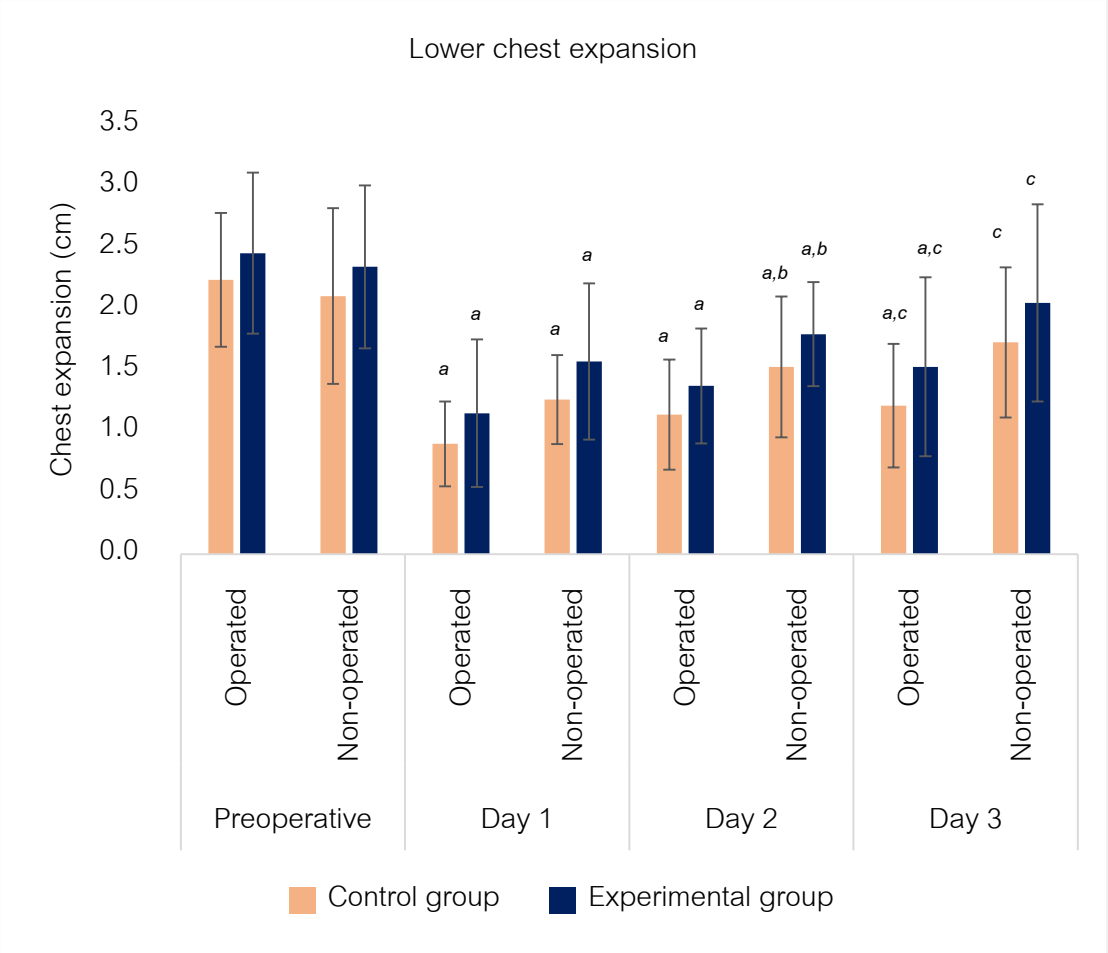


Figure 13 Comparison of lower chest expansion on operated and non-operated sides from preoperative day to the 3rd postoperative day within and between groups

[a] Significant difference within group between preoperative and in each postoperative day (P<0.05).

[b] Significant difference within group between 1st and 2nd postoperative day (P<0.05).

[c] Significant difference within group between 1st and 3rd postoperative day (P<0.05).

4. Pain score

The numeric rating scale was used for assessment pain after lobectomy in this study. The pain score in both groups is shown in Figure 14. The mean pain score was 5.2±1.9 in the control group and 4.8±2.2 in the experimental group on the first operative day. The pain score was highest on the first postoperative day and then gradually decreased on the second and the third postoperative day in both groups ($P<0.05$) . However, three days after the operation, there was still some pain in both groups. The results showed no statistically significant differences in pain score between groups. See Tables 8 for detailed data.

Table 8 Comparison between groups in each day of pain score

Day	Control group	Experimental group	P-value between group
-Preoperative day	0.0±0.0	0.0±0.0	
-Postoperative day			
Day 1	5.2±1.9[a]	4.8±2.2[a]	0.57
Day 2	3.6±1.2[a,b]	3.7±1.9[a,b]	0.92
Day 3	2.7±1.4[a,c,d]	3.1±2.0[a,c]	0.50

Data presented as mean ± standard deviation (cm.)

[a] Significant difference within group between preoperative and each postoperative day ($P<0.05$).

[b] Significant difference within group between 1st and 2nd postoperative day ($P<0.05$).

[c] Significant difference within group between 1st and 3rd postoperative day ($P<0.05$).

[d] Significant difference within group between 2nd and 3rd postoperative day ($P<0.05$).

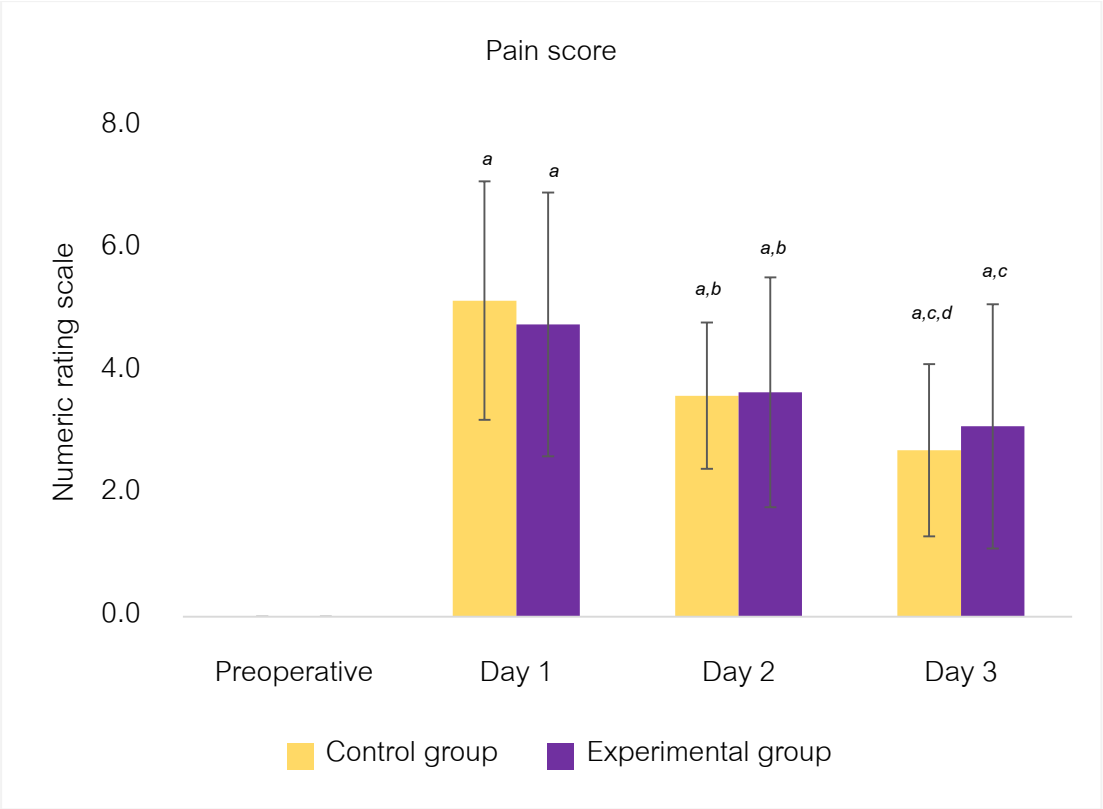


Figure 14 Comparison of pain score from preoperative day to third postoperative day within and between groups

[a] Significant difference within group between preoperative and in each postoperative day (P<0.05).

[b] Significant difference within group between 1st and 2nd postoperative day (P<0.05).

[c] Significant difference within group between 1st and 3rd postoperative day (P<0.05).

[d] Significant difference within group between 2nd and 3rd postoperative day (P<0.05).

5. Functional capacity

The six-minute walk test was used to assess the function capacity. Table 9 shows the six-minute walk distances. At the preoperative day, the mean distances were 417.9±101.0 m. in the control group and 443.8±89.7 m. in the experimental group. The walk distances were not statistically different between the control group and the experimental group at the preoperative day (P=0.42) and at the discharge day (P=0.46). After the lobectomy, the mean reduction of six-minute walk distances was 55.7 m. in the control group and 57.5 m. in the experimental group which were significant lower distance than the preoperative walking distance (P<0.001) . There was no significant difference in the reduction of six-minute walk distances between the control and experimental group on discharge day.

Table 9 Comparison of the six-minute walk distance on preoperative and discharge day within and between groups

Variables	Control group (n=18)	Experimental group (n=18)	P-value
Preoperative	417.9±101.0	443.8±89.7	0.42
Discharge	362.2±107.6*	386.3±84.8*	0.46
∆ Distance	55.7	57.5	

Data presented as mean ± standard deviation (m.)

* Significant difference between preoperative and discharge day (P<0.001).

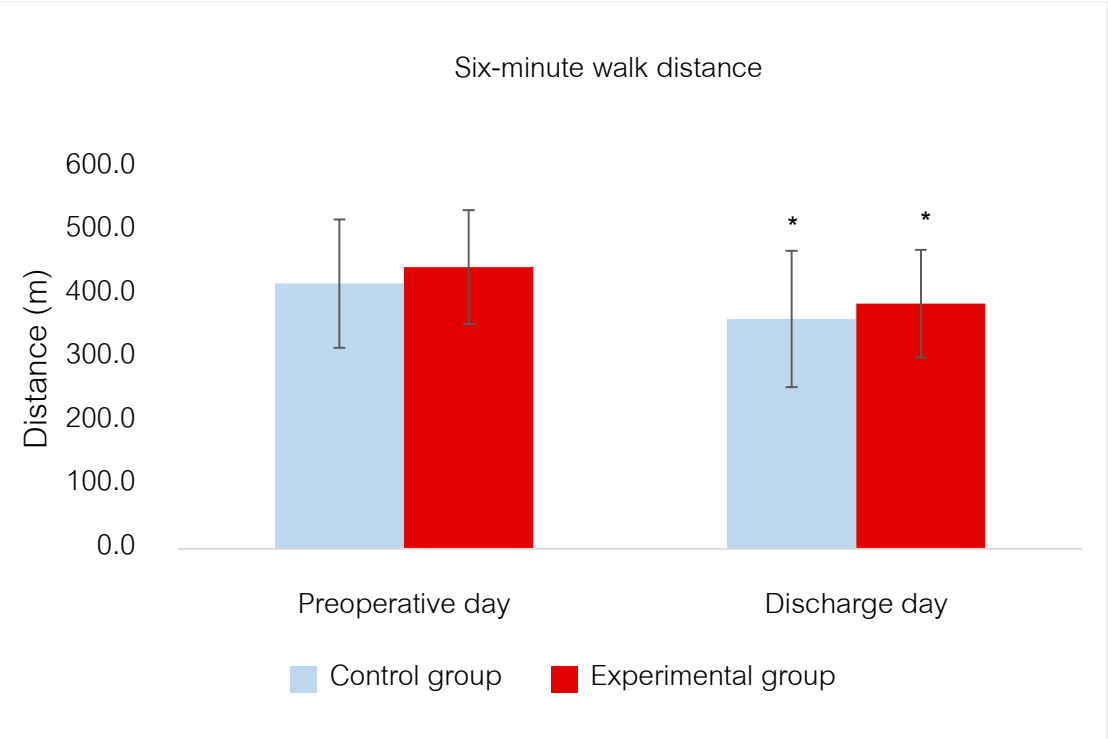


Figure 15 Comparison of six-minute walk distance on preoperative and discharge day within and between groups

* Significant difference between preoperative and discharge day (P<0.001).

CHAPTER 5
DISCUSSION

The goals of the present study were to compare the effect of combined active chest mobilization with physical therapy treatment on chest expansion, pain score, and functional capacity in patients undergoing lobectomy. The main findings of this study showed that combined active chest mobilization with physical therapy treatment was not effective than standard physical therapy treatment in three days after lobectomy.

To date, there have been no studies measuring chest expansion with hemi-thorax assessment in patients undergoing lobectomy. This study is the first study that we investigated the chest expansion on the operated and non-operated sides of patients with lobectomy using cloth tape measurement. The intra-rater reliability of the hemi-thorax chest expansion in healthy subjects was carried out before conducting the main experiment. The results showed that intra-rater reliability of hemi-thorax chest expansion in healthy subjects was excellent. The study of the intra-rater reliability of hemi-thorax chest expansion in healthy subjects was published as a full-text proceeding in the 13th Srinakharinwirot university research conference, 25-26 March 2020 (APPENDIX C) . Therefore, this technique could be used to measure chest expansion in lobectomy patients.

1. Effect on chest expansion

The current study focused on the effect of chest mobilization on chest expansion in lobectomy patients because the pulmonary surgical procedure mainly limited the lung expansion. This study measured chest expansion using cloth tape measurement because it was simple and easy to detect the change of chest expansion. Debouche et al. demonstrated that the cloth tape measurement correlated with the vital capacity and inspiratory capacity (40). Thus, it can be represented indirectly measurement the lung volume. Chest mobilization was performed by moving arms and stretching the chest wall with a deep breathing. The soft tissue and joints around the chest wall were stretched, consequently the chest wall was easily to expand which was

reflected to increase lung volume (16, 52). Therefore, chest mobilization technique applied to patients with lobectomy should be promoted chest expansion and ventilation. The results of the present study showed that there was no significant difference on chest expansion when compared between the experimental and control groups after lobectomy. These were possibly due to the effect of early mobilization and ambulation in which the patients in both groups were received after lobectomy. Early mobilization and ambulation was included in our study in the standard physical therapy treatment. The previous studies showed that the early mobilization or ambulation resulted in increasing ventilation (V_E) by increased tidal volume (V_T) and respiratory rate (53, 54), when patients moved from supine to standing position. In the standing position, rib cage displacement was significantly increased by 63.8% more than in the supine position (53). All participants in this study received early mobilization and encouraged to walk within the first postoperative day and performed until the discharge day. Therefore, the strong effect of early mobilization or ambulation in improving ventilation and lung volume may be contributed to the chest expansion in both groups.

The comparing between the experimental and control groups after lobectomy did not show any significant difference in chest expansion which inconsistent with the study in healthy adults (23), low back pain (24), stroke (25), and COPD patients (26-28). First, the causes of the limitation of chest expansion in the participants of the current study were from surgical wound pain which was different from the previous studies. Second, our study investigated the effect of combined chest mobilization with physical therapy treatment only three days after operation but the previous studies investigated the effect of chest mobilization for six weeks in healthy adults (23) and four weeks in stroke patients (25). Therefore, the acute effect of three days performing chest mobilization combined with physical therapy treatment in the lobectomy patients did not clearly improve chest expansion. The adhesion of the surgical wound was one of the main causes to limit chest expansion in the lobectomy patients and it occurred after wound healing. Chest mobilization may release the adhesion of the surgical wound if

performing continually. It was interesting that the long-term effect of chest mobilization on chest expansion in patients with lobectomy should be investigated.

The upper and lower chest expansion was significant decreases on the first postoperative day and not fully returned to baseline on the third postoperative day in both groups. These may be due to the anesthesia techniques, drug, and the postoperative pain that contributed to deep and slow breathing, changed in lung mechanics, decreased lung ventilation and decreased lung volume (14). Normally, the chest expansion is related to respiratory muscle strength, and lung volume. The higher lung volume is generated by the higher respiratory muscle strength which resulted in larger chest wall movement (15). Nonetheless, the thoracic surgery patients received muscle relaxant drugs and the anesthesia techniques during perioperative contribute to the changes in respiratory function and displacement of the diaphragm muscle which affected in reducing FEV_1 and FRC, leading to decrease lung volume (13, 14). Moreover, the surgical incision and ICD insertion were produced severe postoperative pain which the patients were not able to take a deep breath or cough effectively. This is one of the reasons leading to a decrease in lung volume and accumulates secretion (52). The patients tried to reduce aggressive postoperative pain during breathing by changing to the short of breath (55), using upper chest breathing, and reducing the lower chest expansion. The surgical wound was not completely healed in three days. The pain score was reduced after the operation in both groups, but the patients still had pain during taking a deep breathe. So within three days after operation, the chest expansion was not fully recovered.

However, the lower chest expansion on the non-operated side could return to baseline on the third postoperative day in both control and experiment groups. Elshafie et al. investigated the chest wall motion by plethysmography on the first postoperative day. They found that the chest wall motion was reduced on the operated side but was increased on the non-operated side after lobectomy. This phenomenon could be a mechanism to preserve overall ventilation (19). The results of the present study demonstrated that the lower chest expansion on the non-operated side could be

returned to baseline and these may be explained in a similar mechanism of the preservation in the ventilation of the whole lung.

2. Effect on pain score

Pain score was used to evaluate the perception of surgical wound pain and the patients was asked about their pain score after receiving the physical therapy treatment in each day. The current study demonstrated that the pain scores in both groups were in moderate-to-severe pain (5.2±1.9 in control group and 4.8±2.2 in experimental group) on the first postoperative day (5 6) and were subsided on the second and the third postoperative day.

The thoracic incision line from the surgical techniques, injury of intercostal nerve, and pleura irritation from chest tube drainage were mainly produced postoperative pain after lobectomy (11, 52, 55). The thoracotomy or VATS procedures were operated with the incision of the chest wall between the ribs and cut several muscles to open the thoracic wall. Also, the surgical procedure produced severe postoperative pain (55). The thoracotomy was widely used in lobectomy patients (1) but nowadays the VATS is increasing in operating for lobectomy due to less postoperative pain, faster recovery of respiratory muscle function, lower PPCs, shorter LOS and fewer costs than thoracotomy (2, 3, 52). Brocki et al. found that the VATS technique was used approximately 55% in high-risk patients undergoing lung resection (3). In our study also found that the lobectomy patients operated with the VATS technique was higher than other techniques with approximately 72.20% in the control group and 77.77% in the experimental group. Generally, the ICD was presented after lobectomy to remove fluid and air in the pleural cavity. The irritation of pleura from chest tube drainage induced postoperative pain and produced an aggressive pain during performed an activity (11). All of the factors were induced static and dynamic pain in patients after lobectomy.

The pain score of both groups was not shown a significant difference between groups in each postoperative day. The essential pain management after thoracic surgery was important. It included multiple analgesic agents and adopted with different

techniques, to control pain and reducing the aggressive of pain after surgery (55, 57). Analgesia is the most commonly used for relieving pain during perioperative and postoperative, which including loco-regional anesthesia, opioids, and nonsteroidal anti-inflammatory drugs (NSAID). Loco-regional anesthesia e.g. thoracic epidural analgesia (TEA), thoracic paravertebral block (TPVB), and intercostal nerve block is considered for pain management to be the first choice in thoracic surgery patients. TEA is the gold standard of local anesthesia and usually recommend after thoracic surgery due to better pain relief than opioids patient-controlled analgesia (PCA). However, there are many limitations to use such as the complications during and after the procedure, of the need for skilled doctors for placement, and can cause sympathetic blockade, respiratory depression, and urinary retention. Nowadays, TPVB has been increasingly used for relieving pain in VATS patients due to fewer side effects than TEA. Single-shot of TPVB can be relief pain immediately postoperative period but it cannot cover the pain in a long period. Intercostal nerve block via single-shot or continuous infusion techniques were used to relieve pain but only continuous infusion technique was provided pain control comparable to TEA. So, this technique was used for pain control especially in thoracotomy patients. Opioids were commonly used in PCA, especially, morphine is largely used due to rapid onset and medium duration. Fentanyl and sufentanil are faster onset time and shorter duration when compared with morphine. Codeine and tramadol are commonly used in the very postoperative period. However, these opioids should be limited due to increased risk of side effects including hypotension, respiratory depression, itching, nausea, vomit, bowel ileus, and confusion. NSAID is used for relieving pain in patients with problems of the side effects of opioids. Though these drugs were considered in patients with problems from using opioids, there were recurring risks like kidney problems, gastric bleeding, and effects on platelet aggregation. The important of pain management by analgesic agents during and after operation must be done to prevent the postoperative pain (57). In the current study, the surgical procedures and length time of ICD, in which the factors for increasing the pain were not shown a difference between groups. Thus, the reducing pain after surgery and

a non-difference of pain score between the groups in this study may be from the effect of analgesia which both groups were received in the same management.

When taking a deep breath, it induced a stretch at the incision line leading to severe pain on the surgical wound. The expiratory muscles will be contracted to prevent stretching of the skin around the incision for reducing pain during breathing. The prevention of increasing pain would limit the stretching of the incision line during inspiration (55). In clinical practice, the pillow is used to support the surgical wound for reducing pain during training a breathing exercise and cough (52). The patients in the experimental group were received chest mobilization which performed a stretching at the incision line during inspiration. This technique might generate more pain for the surgical wound in these patients. The result in the current study showed that the pain score was not different between control and experimental groups in all three days after lobectomy. The chest mobilization technique did not aggressive pain during treatment, accordingly, the patients could follow the procedure of chest mobilization which moved limbs or trunk with deep breathing. Therefore, applying the active chest mobilization for lobectomy patients would be safe and did not aggravate the postoperative pain after lobectomy.

This study demonstrated that the pain score was gradually reduced in each postoperative day in both groups. The pain score was reduced after lobectomy due to pain management with patient-controlled analgesia. After lobectomy, patients received various analgesia for relieving the pain every day. The dose of analgesia was depended on the pain perceptions of individual patients. In our study, the mean difference of postoperative pain was 1.1 units on the second postoperative day and was 0.6 units on the third postoperative day of the experimental group, and was 1.6 units on the second postoperative day and was 0.9 units on the third postoperative day of the control group. These were in the range of the reported minimal clinical important difference (MCID) of pain from a recent systematic review (58). The systematic review conducted in postoperative pain, trauma, abdominal pain, and mixed patients at emergency showed that the MCID was ranged 0.8-4.0 unit (58). Kendrick et al. evaluated acute pain using

the numeric rating scale (NRS) in the emergency department. The NRS measurement was repeated every 20 minutes for 2 hours, or until no pain or left the emergency department. The MCID of pain was reported approximately 1.39 (59). The changes in pain score in the current study demonstrated that the combined chest mobilization with physical therapy treatment affected the recovery of pain similar to the standard physical therapy treatment.

3. Effect on functional capacity

There have been evaluated functional capacity after lung resection using a cardiopulmonary exercise test to measure peak oxygen uptake (8). In this study, a 6MWT was used to evaluated functional capacity as it is easier to perform and represents the ability of patients in activities of daily living (33). The 6MWT was a good correlation with peak oxygen uptake (49) and moderate-to-strong relationship to maximum oxygen uptake or peak oxygen uptake (60).

The results did not show the significant differences in functional capacity between the experiment and control groups after lobectomy. All of the lobectomy patients in both groups received the same early mobilization/ambulation protocol from the first postoperative day to discharge day which might be a factor in improving functional capacity. Although, the combined chest mobilization with physical therapy treatment did not improve the chest expansion more than the standard physical therapy treatment, the evidence showing that physical therapy treatment especially early mobilization improved the functional capacity in patients after lobectomy (61). Early mobilization/ambulation in postoperative patients aims to stress the cardiopulmonary system to increase V_E and cardiac output (52), which results in increasing oxygen supply to the working muscle at a sufficient level.

This study showed that the functional capacity after lobectomy was reduced in both groups. The reduction of functional capacity was affected by the postoperative pain and chest wall restriction after surgery more than the direct effect of lung parenchyma loss (62). 6MWT measured a maximum walk distance in six minutes. The

participants should walk as far as possible in six minutes. In the acute period after operation, the postoperative pain from the incision wound and chest drain (52) was the main factor to limit the pace and intensity of walking (53) and affected to reduce the walk distance.

This study showed a similar results to the previous studies (62, 63). Win et al. demonstrated that the exercise capacity measured by shuttle walk was reduced in lobectomy patients and the mean reduction was 125.0 meters at 1 month and 64.0 meters at 6 months (62). Nery et al. studied in patients with lung resection including segmentectomy, lobectomy, bi-lobectomy, and pneumonectomy, and the common use of the surgical technique was thoracotomy. The patients performed breathing exercises 10 cycles/session, two sessions/day for 7 days. The results showed that the mean reduction of 6MWD on the 7^{th} postoperative day was 147.2 meters (63). The current study showed that the mean reduction of six-minute walk distances was 55.7 meters in the control group and 57.5 meters in the experimental group (range 3-21 days, mean 6 days in the control group and mean 8 days in the experimental group). The reduction of 6MWD in this study was lower than the previous studies may be due to the different surgical techniques (VATS versus thoracotomy) , and the protocol of treatments especially the early mobilization. Most of the patients in this study were operated with the VATS technique, while thoracotomy was used to operate lung resection in the previous study. Moreover, early mobilization after surgery improves cardiopulmonary response and ventilation (53). From these reasons, 6MWD found in this study is higher than in the previous studies.

4. Clinical implications

The combined chest mobilization with physical therapy treatment improved the chest expansion and reduced pain similar to standard physical therapy treatment in the early postoperative period. The chest mobilization technique could be applied for the patients undergoing lobectomy as it was safe and did not aggravate the postoperative pain. In this study, there were high compliance of participants performing and

completing the intervention and no participants drop out, which showing that the chest mobilization was accepted in patients undergoing lobectomy.

5. Study limitations

In this study, we investigated the effect of combined chest mobilization with physical therapy treatment on the first to third postoperative days and the results showed the same effects on chest expansion and pain when compared with standard physical therapy treatment. The patients in the acute period had moderate-to-severe postoperative pain which was the main factor to limit chest expansion. We found that the chest mobilization did not aggravate pain during training in this period but did not follow the program until discharge or given to the home program. In the long-term period, when the pain is subsided, the chest expansion would be limited from the wound adhesion. Chest mobilization may effect to release adhesion and improve chest expansion. For the further study, the effect of chest mobilization on chest expansion in the long-term period after lobectomy should be investigated.

6. Conclusion

The combined chest mobilization with physical therapy treatment improves chest expansion and reduces pain in patients undergoing lobectomy similar to the standard physical therapy treatment and it is not more effective than the standard physical therapy treatment on functional capacity in the early period after lobectomy.

REFERENCES

1. Boffa DJ, Allen MS, Grab JD, Gaissert HA, Harpole DH, Wright CD. Data from the society of thoracic surgeons general thoracic surgery database: the surgical management of primary lung tumors. J Thorac Cardiovasc Surg. 2008;135(2):247-54.

2. Agostini P, Reeve J, Dromard S, Singh S, Steyn RS, Naidu B. A survey of physiotherapeutic provision for patients undergoing thoracic surgery in the U.K. Physiotherapy. 2013;99(1):56-62.

3. Brocki BC, Andreasen JJ, Langer D, Souza DS, Westerdahl E. Postoperative inspiratory muscle training in addition to breathing exercises and early mobilization improves oxygenation in high-risk patients after lung cancer surgery: a randomized controlled trial. Eur J Cardiothorac Surg. 2016;49(5):1483-91.

4. Miskovic A, Lumb AB. Postoperative pulmonary complications. Br J Anaesth. 2017;118(3):317-34.

5. Avila AC, Fenili R. Incidence and risk factors for postoperative pulmonary complications in patients undergoing thoracic and abdominal surgeries. Rev Col Bras Cir. 2017;44(3):284-92.

6. Berend N, Woolcock AJ, Marlin GE. Effects of lobectomy on lung function. Thorax. 1980;35:145-50.

7. Kigin CM. Chest physical therapy for the postoperative or traumatic injury patient. Phys Ther. 1981;61:1724-36.

8. Bolliger CT, Jordan P, Solèr M, Stulz P, Tamm M, Wyser C, et al. Pulmonary function and exercise capacity after lung resection. Eur Respir J. 1996;9(3):415-21.

9. Kearney D, Lee T, Reilly J, Decamp M, Sugarbaker D. Assessment of operative risk in patients undergoing lung resection. Chest 1994;105:753-59.

10. Cukic V. Reduction of pulmonary function after surgical lung resections of different volume. Med Arch. 2014;68(4):231-5.

11. Refai M, Brunelli A, Salati M, Xiume F, Pompili C, Sabbatini A. The impact of chest tube removal on pain and pulmonary function after pulmonary resection. Eur J

Cardiothorac Surg. 2012;41(4):820-2.

12. Watchie J. Cardiovascular and pulmonary physical therapy: A clinical manual. 2nd ed. Missouri: Elsevier; 2010.

13. Karcz M, Papadakos PJ. Respiratory complications in the postanesthesia care unit: A review of pathophysiological mechanisms. Can J Respir Ther. 2013;49(4):21-9.

14. Saraswat V. Effects of anaesthesia techniques and drugs on pulmonary function. Indian J Anaesth. 2015;59(9):557-64.

15. Lanza FdC, Camargo AAd, Archija LRF, Selman JPR, Malaguti C, Corso SD. Chest wall mobility is related to respiratory muscle strength and lung volumes in healthy subjects. Respir Care. 2013;58(12):2107-12.

16. Leelarungrayub D. Chronic obstructive pulmonary disease-current concepts and pratice. Shanghai: InTech; 2012.

17. Frownfelter D, Dean E. Cardiovascular and pulmonary physical therapy: Evidence to practice. 5th ed. Vancouver: Elsevier; 2012.

18. Reeve J, Denehy L, Stiller K. The physiotherapy management of patients undergoing thoracic surgery: a survey of current practice in Australia and New Zealand. Physiother Res Int. 2007;12(2):59-71.

19. Elshafie G, Kumar P, Motamedi-Fakhr S, Iles R, Wilson RC, Naidu B. Measuring changes in chest wall motion after lung resection using structured light plethysmography: a feasibility study. Interact Cardiovasc Thorac Surg. 2016;23(4):544-7.

20. Benzo R, Kelley GA, Recchi L, Hofman A, Sciurba F. Complications of lung resection and exercise capacity: a meta-analysis. Respir Med. 2007;101(8):1790-7.

21. Varela G, Novoa NM, Agostini P, Ballesteros E. Chest physiotherapy in lung resection patients: state of the art. Semin Thorac Cardiovasc Surg. 2011;23(4):297-306.

22. Kendall F, Abreu P, Pinho P, Oliveira J, Bastos P. The role of physiotherapy in patients undergoing pulmonary surgery for lung cancer. A literature review. Rev Port Pneumol. 2017:1-9.

23. Jung JH. The effect of thoracic region self-mobilization on chest expansion and pulmonary function. J Phys Ther Sci. 2015;27(9):2779–81.

24. Babina R, Mohanty PP, Pattnaik M. Effect of thoracic mobilization on respiratory parameters in chronic non-specific low back pain: A randomized controlled trial. J Back Musculoskelet Rehabil. 2016;29(3):587-95.

25. Park SJ, Lee JH, Min KO. Comparison of the effects of core stabilization and chest mobilization exercises on lung function and chest wall expansion in stroke patients. J Phys Ther Sci. 2017;29(7):1144–7.

26. de Sa RB, Pessoa MF, Cavalcanti AGL, Campos SL, Amorim C, Dornelas de Andrade A. Immediate effects of respiratory muscle stretching on chest wall kinematics and electromyography in COPD patients. Respir Physiol Neurobiol. 2017;242:1-7.

27. Leelarungrayub D, Pothongsunun P, Yankai A, Pratanaphon S. Acute clinical benefits of chest wall-stretching exercise on expired tidal volume, dyspnea and chest expansion in a patient with chronic obstructive pulmonary disease: a single case study. J Bodyw Mov Ther. 2009;13(4):338-43.

28. Parmar D, Bhise A. The immediate effect of chest mobilization technique on chest expansion in patients of COPD with restrictive impairment. Indian J Physiother Occup 2015;4(6):2413-6.

29. Parmar D, Bhise A. The immediate effect of chest mobilization technique on oxygen saturation in patients of COPD with restrictive impairment. Indian J Physiother Occup 2015;9(3):98-102.

30. Reeve J, Stiller K, Nicol K, McPherson KM, Birch P, Gordon IR, et al. A postoperative shoulder exercise program improves function and decreases pain following open thoracotomy: a randomised trial. J Physiother. 2010;56(4):245-52.

31. Akhtar AS, Faizan A, Seema G, Sushant S. Effect of respiratory muscle stretch gymnastics on pain, chest expansion, pulmonary functions and functional capacity in phase 1 post-operative CABG patients. J Cardiol Curr Res. 2015;2(6).

32. ATS Statement: Guidelines for the six-minute walk test. Am J Respir Crit Care Med. 2002;166:111–7.

33. Wise RA, Brown CD. Minimal clinically important differences in the six-minute walk test and the incremental shuttle walking test. Copd. 2009;2(1):125-9.

34. Canet J, Mazo V. Postoperative pulmonary complications. Minerva Anestesiol. 2010;76:138-43.

35. Sultanpuram S, Alaparthi GK, Krishnakumar SK, Ottayil ZC. Physiotherapy practice patterns for management of patients undergoing thoracic surgeries in India: A Survey. Surg Res Pract. 2016;2016:11.

36. Restrepo RD, Wettstein R, Wittnebel L, Tracy M. Incentive spirometry: 2011. Respir Care. 2011;56(10):1600-4.

37. Strickland SL, Rubin BK, Drescher GS, Haas CF, O'Malley CA, Volsko TA, et al. AARC clinical practice guideline: effectiveness of nonpharmacologic airway clearance therapies in hospitalized patients. Respir Care. 2013;58(12):2187-93.

38. Reeve JC, Nicol K, Stiller K, McPherson KM, Birch P, Gordon IR, et al. Does physiotherapy reduce the incidence of postoperative pulmonary complications following pulmonary resection via open thoracotomy? A preliminary randomised single-blind clinical trial. Eur J Cardiothorac Surg. 2010;37(5):1158-66.

39. Bockenhauer SE, Chen H, Julliard KN, Weedon J. Measuring thoracic excursion: Reliability of the cloth tape measure technique. J Am Osteopath Assoc. 2007;107:191-6.

40. Debouche S, Pitance L, Robert A, Liistro G, Reychler G. Reliability and reproducibility of chest wall expansion measurement in young healthy adults. J Manipulative Physiol Ther. 2016;39(6):443-9.

41. LaPier TK, Cook A, Droege K, Oliverson R, Rulon R, Stuhr E, et al. Intertester and intratester reliability of chest excursion measurement in subjects without impairment. Cardiopulmonay Phys Ther. 2000;11(3):94-8.

42. Malaguti C, Rondelli RR, Souza LMd, Domingues M, Corso SD. Reliability of chest wall mobility and its correlation with pulmonary function in patients with chronic obstructive pulmonary disease. Respir Care. 2009;54(12):1703-11.

43. Fisher LR, Cawley MI, Holgate ST. Relation between chest expansion, pulmonary function, and exercise tolerance in patients with ankylosing spondylitis. Ann Rheum Dis. 1990;49:921-5.

44. Olsén MF, Lindstrand H, Broberg JL, Westerdahl E. Measuring chest expansion; A

study comparing two different instructions. Adv Physiother. 2011;13(3):128-32.

45. Bockenhauer SE, Julliard KN, LO KS, Huang E, Sheth AM. Quantifiable effects of osteopathic manipulative techniques on patients with chronic asthma. J Am Osteopath Assoc. 2002;102(7):371-5.

46. Li L, Liu X, Herr K. Postoperative pain intensity assessment: a comparison of four scales in Chinese adults. Pain Med. 2007;8(3):223-34.

47. Win T, Jackson A, Groves AM, Sharples LD, Charman SC, Laroche CM. Comparison of shuttle walk with measured peak oxygen consumption in patients with operable lung cancer. Thorax. 2006;61(1):57-60.

48. Starobin D, Kramer RM, Yarmolovsky A, Bendayan D, Rosenberg I, Sulkes J, et al. Assessment of functional capacity in patients with chronic obstructive pulmonary disease: correlation between cardiopulmonary exercise, 6 minute walk and 15 step exercise oximetry test. Isr Med Assoc J. 2006;8:460-3.

49. Ross RM, Murthy JN, Wollak ID, Jackson AS. The six minute walk test accurately estimates mean peak oxygen uptake. BMC Pulm Med. 2010;10:31.

50. Holland AE, Spruit MA, Troosters T, Puhan MA, Pepin V, Saey D, et al. An official European Respiratory Society/American Thoracic Society technical standard: field walking tests in chronic respiratory disease. Eur Respir J. 2014;44(6):1428-46.

51. Portney LG, Watkins MP. Foundations of clinical research: applications to practice. New Jersey: Prentice Hall Inc; 2000.

52. Ahmad AM. Essentials of Physiotherapy after Thoracic Surgery: What Physiotherapists Need to Know. A Narrative Review. Korean J Thorac Cardiovasc Surg. 2018;51(5):293-307.

53. Zafiropoulos B, Alison JA, McCarren B. Physiological responses to the early mobilisation of the intubated, ventilated abdominal surgery patient. Aust J Physiother. 2004;50(2):95-100.

54. Orfanos P, Ellis E, Johnston C. Effects of deep breathing exercises and ambulation on pattern of Ventilation in post-operative patients. Aust J Physiother. 1999;45(3):173-82.

55. Gerner P. Postthoracotomy pain management problems. Anesthesiol Clin.

2008;26(2):355-67.

56. Gerbershagen HJ, Rothaug J, Kalkman CJ, Meissner W. Determination of moderate-to-severe postoperative pain on the numeric rating scale: a cut-off point analysis applying four different methods. Br J Anaesth. 2011;107(4):619-26.

57. Rizzi A, Raveglia F, Scarci M, Cioffi U, Baisi A. The best strategy to control pain after thoracic surgery: multimodal strategy against pain. Video-Assisted Thoracic Surgery. 2019;4:26-.

58. Olsen MF, Bjerre E, Hansen MD, Hilden J, Landler NE, Tendal B, et al. Pain relief that matters to patients: systematic review of empirical studies assessing the minimum clinically important difference in acute pain. BMC Med. 2017;15(1):35.

59. Kendrick DB, Strout TD. The minimum clinically significant difference in patient-assigned numeric scores for pain. Am J Emerg Med. 2005;23(7):828-32.

60. Ha D, Mazzone PJ, Ries AL, Malhotra A, Fuster M. The Utility of Exercise Testing in Patients with Lung Cancer. J Thorac Oncol. 2016;11(9):1397-410.

61. Sivakumar T, Maiya AG. Effect of graded incremental mobilization on exercise tolerance following lung resection surgery. Indian J Physiother Occup Ther. 2008;2(3):9-12.

62. Win T, Groves AM, Ritchie AJ, Wells FC, Cafferty F, Laroche CM. The effect of lung resection on pulmonary function and exercise capacity in lung cancer patients. Respir Care. 2007;52(6):720-6.

63. Nery FP, Lopes AJ, Domingos DN, Cunha RF, Peixoto MG, Higa C, et al. CPAP increases 6-minute walk distance after lung resection surgery. Respir Care. 2012;57(3):363-9.

APPENDICES

APPENDIX A

CERTIFICATE OF APPROVAL

เลขที่ 038/2562

คณะกรรมการจริยธรรมเพื่อการวิจัยสถาบันโรคทรวงอก
กรมการแพทย์
กระทรวงสาธารณสุข

โครงการวิจัย : "ผลของการฝึกการเคลื่อนไหวทรวงอกต่อการขยายตัวของทรวงอกและอาการปวดแผลในผู้ป่วยหลังผ่าตัดกลีบปอด: การศึกษาแบบสุ่ม"(Effect of chest mobilization on chest expansion and pain in patients undergoing lobectomy: A randomized controlled trial)

ผู้ดำเนินการวิจัย : นางสาวนภาพร แววทอง
นิสิตปริญญาโท สาขากายภาพบำบัด
คณะกายภาพบำบัด มหาวิทยาลัยศรีนครินทรวิโรฒ

สถานที่ทำการวิจัย : สถาบันโรคทรวงอก

เอกสารที่ได้รับการพิจารณามีดังนี้

1. แบบเสนอโครงการวิจัย (research project)
2. หนังสือให้ความยินยอมเข้าร่วมในโครงการวิจัย
3. คำชี้แจงอาสาสมัคร (Information Sheet)
4. แบบบันทึกการเก็บข้อมูลวิจัย
5. แผ่นบรรจุข้อมูลโครงการวิจัย

คณะกรรมการจริยธรรมเพื่อการวิจัยสถาบันโรคทรวงอก กรมการแพทย์ กระทรวงสาธารณสุข อนุมัติในแง่จริยธรรมให้ดำเนินการศึกษาวิจัยเรื่องข้างต้นได้

.....
(นายแพทย์ธรรมรัฐ ฉันทแดนสุวรรณ) ประธานกรรมการ

.....
(นายอุดม แท้วิริยะกุล) เลขานุการกรรมการ

รับรองวันที่ : 21 มี.ค. 2562
วันหมดอายุ : 20 มี.ค. 2563

APPENDIX B

REVISE CERTIFICATE OF APPROVAL

เลขที่ 072/2562

คณะกรรมการจริยธรรมเพื่อการวิจัยสถาบันโรคทรวงอก
กรมการแพทย์
กระทรวงสาธารณสุข

โครงการวิจัย : "ผลของการฝึกการเคลื่อนไหวทรวงอกร่วมกับการรักษาทางกายภาพบำบัดต่อการขยายตัวของทรวงอกและอาการปวดแผลในผู้ป่วยหลังผ่าตัดกลีบปอด: การศึกษาแบบสุ่ม"(Effect of combined chest mobilization with physical therapy treatment on chest expansion and pain in patients undergoing lobectomy: A randomized controlled trial)

ผู้ดำเนินการวิจัย : ผู้ช่วยศาสตราจารย์ ดร. สุกัลยา กฤษณเกรียงไกร
อาจารย์ประจำสาขาวิชา กายภาพบำบัด
สถานที่ปฏิบัติงาน คณะกายภาพบำบัด มหาวิทยาลัยศรีนครินทรวิโรฒ

สถานที่ทำการวิจัย : สถาบันโรคทรวงอก

เอกสารที่ได้รับการพิจารณามีดังนี้

1. บันทึกข้อความ ขออนุมัติการเปลี่ยนแปลงชื่อเรื่องโครงการวิจัยและหัวหน้าโครงการวิจัย
2. สำเนาใบรับรองจาก คณะกรรมการจริยธรรมเพื่อการวิจัยสถาบันโรคทรวงอก กรมการแพทย์ กระทรวงสาธารณสุข

คณะกรรมการจริยธรรมเพื่อการวิจัยสถาบันโรคทรวงอก กรมการแพทย์ กระทรวงสาธารณสุข อนุมัติในแง่จริยธรรมให้ดำเนินการศึกษาวิจัยเรื่องข้างต้นได้

.....
(นายแพทย์ธรรมรัฐ ฉันทแดนสุวรรณ) ประธานกรรมการ

.....
(นายอุดม แท้วิริยะกุล) เลขานุการกรรมการ

รับรองวันที่ : 14 พ.ค. 2562

APPENDIX C

PUBLISHED RELIABILITY OF HEMI-THORAX CHEST EXPANSION


CONFERENCE
PROCEEDINGS
การประชุมวิชาการระดับชาติ
มศว วิจัย
ครั้งที่
13
ISBN : 978-616-296-209-7
The 13th Srinakharinwirot University Research Conference
สถาบันยุทธศาสตร์ทางปัญญาและวิจัย
มหาวิทยาลัยศรีนครินทรวิโรฒ
Research SWU

การประชุมวิชาการระดับชาติ "มศว วิจัย" ครั้งที่ 13
วันที่ 25-26 มีนาคม 2563 มหาวิทยาลัยศรีนครินทรวิโรฒ

SWURES13-073 ความน่าเชื่อถือภายในของผู้วัดในการวัดการขยายตัวของทรวงอกแบบครึ่งรอบทรวงอกในอาสาสมัครสุขภาพดี: การศึกษาเบื้องต้น

INTRA-RATER RELIABILITY OF THE HEMI-THORAX CHEST EXPANSION IN HEALTHY SUBJECTS: A PRELIMINARY STUDY

นภาพร แววทอง* *สุกัลยา กฤษณเกรียงไกร*

Napaporn Vaewthong*, *Sukalya kritsanakriengkrai*

คณะกายภาพบำบัด มหาวิทยาลัยศรีนครินทรวิโรฒ

Faculty of Physical Therapy, Srinakharinwirot University

***Corresponding author, E-mail:** oil_moyice@hotmail.com*

บทคัดย่อ

ผู้ป่วยที่ได้รับการผ่าตัดปอดจะมีการขยายตัวของทรวงอกสองข้างไม่สมมาตรกัน การวัดการขยายตัวของทรวงอกแบบครึ่งรอบทรวงอกจึงน่าจะมีความเหมาะสมในการตรวจประเมินผู้ป่วยกลุ่มนี้ การศึกษานี้เป็นการศึกษาเบื้องต้น โดยมีวัตถุประสงค์เพื่อหาความเชื่อถือภายในของผู้วัดในการวัดการขยายตัวของทรวงอกแบบครึ่งรอบทรวงอก โดยทำการศึกษาในอาสาสมัครที่มีสุขภาพดีจำนวน 10 คน ประกอบด้วยเพศชาย 4 คน และเพศหญิง 6 คน อายุเฉลี่ย 30.0±1.6 ปี วัดการขยายตัวของทรวงอกส่วนบนและส่วนล่างในแต่ละข้างของทรวงอกโดยใช้สายวัด ตำแหน่งของการวัดการขยายตัวของทรวงอกส่วนบนด้านหน้าอยู่ที่ระดับช่องระหว่างกระดูกซี่โครงซี่ที่ 3 ของแนวกึ่งกลางของกระดูกไหปลาร้าและลากผ่านมาบริเวณกึ่งกลางของกระดูกหน้าอก และด้านหลังอยู่ที่แนวของกระดูกสันหลังส่วนอกชิ้นที่ 5 สำหรับตำแหน่งของการวัดการขยายตัวของทรวงอกส่วนล่างด้านหน้าอยู่ที่ลิ้นปี่ และด้านหลังอยู่ที่แนวของกระดูกสันหลังส่วนอกชิ้นที่ 10 ผลการศึกษาพบว่าความน่าเชื่อถือภายในของผู้วัดในการวัดการขยายตัวของทรวงอกแบบครึ่งรอบทรวงอกของส่วนบนและส่วนล่างทั้งด้านซ้ายและด้านขวามีความน่าเชื่อถืออยู่ในระดับดีมาก (ICC = 0.92 ของทรวงอกส่วนบนด้านซ้าย ICC = 0.98 ของทรวงอกส่วนบนด้านขวา และ ICC = 0.93 ของทรวงอกส่วนล่างด้านซ้าย ICC = 0.91 ของทรวงอกล่างด้านขวา) การศึกษาครั้งนี้สรุปได้ว่าการวัดการขยายตัวของทรวงอกแบบครึ่งรอบทรวงอกมีความน่าเชื่อถือภายในของผู้วัดสูงและสามารถนำวิธีการวัดนี้ไปประยุกต์ใช้ต่อไป

คำสำคัญ: ความน่าเชื่อถือ การขยายตัวของทรวงอก ครึ่งรอบทรวงอก

Abstract

Asymmetrical chest movement are commonly found in lung resection patients. The hemi-thorax chest expansion may appropriate for assessing in these patients. The objective of this preliminary study is to investigate intra-rater reliability of the hemi-thorax chest expansion measurement in healthy subjects. Ten healthy subjects (6 female, 4 male), mean age 30.0±1.6 years were participated. The hemi-thorax chest expansion measurement of upper and lower chest using cloth tape was performed. The anterior

anatomical mark was at the 3rd intercostal space from the clavicular line and pass to the mid sternum and the posterior anatomical mark was at the level of the 5th thoracic spinous process for the upper chest expansion. For the lower chest expansion, the anterior anatomical mark was at the xiphoid process and the posterior anatomical mark was at the level of the 10th thoracic spinous process. The results of this study showed that the intraclass correlation coefficients for intra-rater reliability of the hemi-thorax chest expansion for the left and right sides of the upper and lower chest expansion provided the excellent reliability (ICC = 0.92 for the left upper chest, ICC = 0.98 for the right upper chest, ICC = 0.93 for the left lower chest and ICC = 0.91 for the right lower chest). In conclusion, the intra-rater reliability of hemi-thorax chest expansion measurement was excellent and could be used to measure this method for further study.

Keyword: Reliability, Chest expansion, Hemi-thorax

บทนำ

ผู้ป่วยที่ได้รับการผ่าตัดปอดจะมีการเคลื่อนไหวของทรวงอกสองข้างไม่สมมาตรกัน การตรวจประเมินการวัดการขยายตัวของทรวงอกแต่ละด้านน่าจะมีความเหมาะสมในการตรวจประเมินผู้ป่วยกลุ่มนี้ จากการศึกษาก่อนหน้ามีการใช้เครื่อง structured light plethysmography วัดการขยายตัวของทรวงอกซีกซ้ายและซีกขวาพบว่ามีการขยายตัวไม่เท่ากัน โดยข้างที่ได้รับการผ่าตัดมีการขยายตัวน้อยกว่าข้างที่ไม่ได้รับการผ่าตัด [1] แต่เครื่องดังกล่าวมีข้อจำกัดในการนำไปใช้ในทางคลินิก เนื่องจากต้องใช้ผู้เชี่ยวชาญทางด้านเทคโนโลยีและเป็นเครื่องมือที่มีราคาสูง

การใช้สายวัดเป็นวิธีการตรวจประเมินการขยายตัวของทรวงอกที่ได้รับความนิยมและแพร่หลายในทางคลินิกเนื่องจากเป็นวิธีที่สะดวก ติดตามผลการรักษาได้ง่าย และมีความน่าเชื่อถือสูง [2, 3] วิธีการวัดการขยายตัวของทรวงอกที่ใช้กันอยู่จะเป็นการวัดแบบเส้นรอบวงรอบทรวงอก โดยกำหนดตำแหน่งอ้างอิงของการวัดทรวงอกส่วนบน ได้แก่ ด้านหน้าอยู่ที่บริเวณช่องระหว่างกระดูกซี่โครงซี่ที่ 3 ของแนวกึ่งกลางของกระดูกไหปลาร้าและด้านหลังอยู่ที่แนวกระดูกสันหลังส่วนอกชิ้นที่ 5 ในส่วนของตำแหน่งอ้างอิงของการวัดการขยายตัวของทรวงอกส่วนล่าง ได้แก่ ด้านหน้าอยู่ที่บริเวณลิ้นปี่และด้านหลังอยู่ที่บริเวณแนวของกระดูกสันหลังส่วนอกชิ้นที่ 10 [2, 3] โดยการศึกษาของ Bockenhauer, S.E. และคณะ (2007) ทำการวัดการขยายตัวของทรวงอกในกลุ่มตัวอย่างที่มีสุขภาพดี ได้ค่าความน่าเชื่อถือภายในของผู้วัดของทรวงอกส่วนบน ICC เท่ากับ 0.86 และของทรวงอกส่วนล่าง ICC เท่ากับ 0.81 [2] และการศึกษาของ Debouche, S. และคณะ (2016) ได้ศึกษาการขยายตัวของทรวงอกในคนหนุ่มสาว พบว่ามีค่าความน่าเชื่อถือภายในของผู้วัดของทรวงอกส่วนบน ICC เท่ากับ 0.95 และของทรวงอกส่วนล่าง ICC เท่ากับ 0.94 [3] อย่างไรก็ดีการศึกษาทั้งสองการศึกษาที่ผ่านมานั้นเป็นการวัดการขยายตัวของทรวงอกแบบเส้นรอบวงรอบทรวงอก ยังไม่เคยมีการศึกษาใดทำการวัดการขยายตัวของทรวงอกแบบครึ่งรอบทรวงอกโดยใช้สายวัด

การวัดแบบเส้นรอบวงรอบทรวงอกจะประเมินได้ดีในผู้ที่มีการขยายตัวของทรวงอกทั้ง 2 ข้างเท่ากัน สำหรับการผ่าตัดปอดข้างใดข้างหนึ่งทำให้ทรวงอกข้างนั้นขยายตัวได้น้อยกว่าข้างที่ไม่ได้รับการผ่าตัด [1] การวัดแบบเส้นรอบวงรอบทรวงอกจึงไม่ได้แสดงถึงการขยายตัวที่ลดลงของข้างที่ได้รับการผ่าตัดได้ชัดเจน การวัดแบบครึ่งรอบทรวงอกจึงจะทำให้สามารถบ่งบอกการขยายตัวของทรวงอกที่ลดลงในแต่ละข้างได้ อีกทั้งยังสามารถติดตามผลการรักษาหลังการผ่าตัดได้ถูกต้องกับส่วนที่มีปัญหาได้ดีกว่า และมีประโยชน์ในการประเมินผลการรักษาได้อีกด้วย แต่ในการวัดแบบครึ่งรอบทรวงอกยังไม่มีการกำหนดวิธีการวัดและไม่เคยมีงานวิจัยใดทำ

มาก่อน การศึกษาครั้งนี้จึงเป็นงานแรกที่ได้กำหนดตำแหน่งและวิธีการวัดแบบครึ่งรอบทรวงอกและทำการหาค่าความน่าเชื่อถือภายในของผู้วัด เพื่อให้เกิดความมั่นใจในการนำวิธีการวัดนี้ไปใช้ในการตรวจประเมินผู้ป่วยที่ได้รับการผ่าตัดปอดต่อไป

วัตถุประสงค์ของงานวิจัย

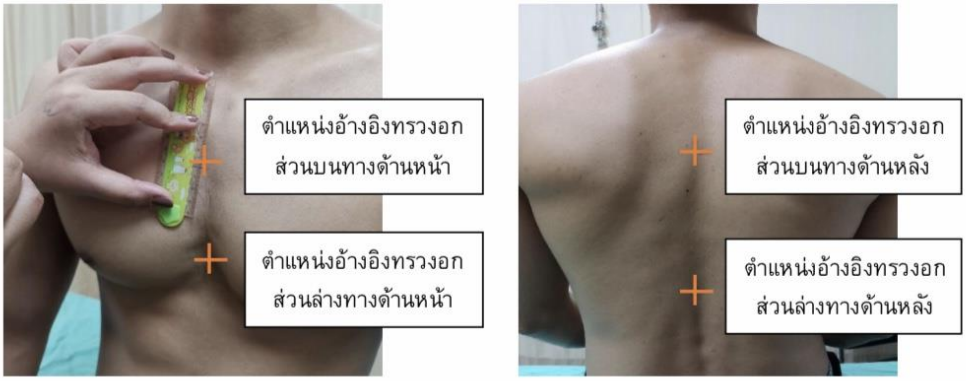
เพื่อหาค่าความเชื่อถือภายในของผู้วัดในการวัดการขยายตัวของทรวงอกแบบครึ่งรอบทรวงอกในอาสาสมัครสุขภาพดี

วิธีดำเนินการวิจัย

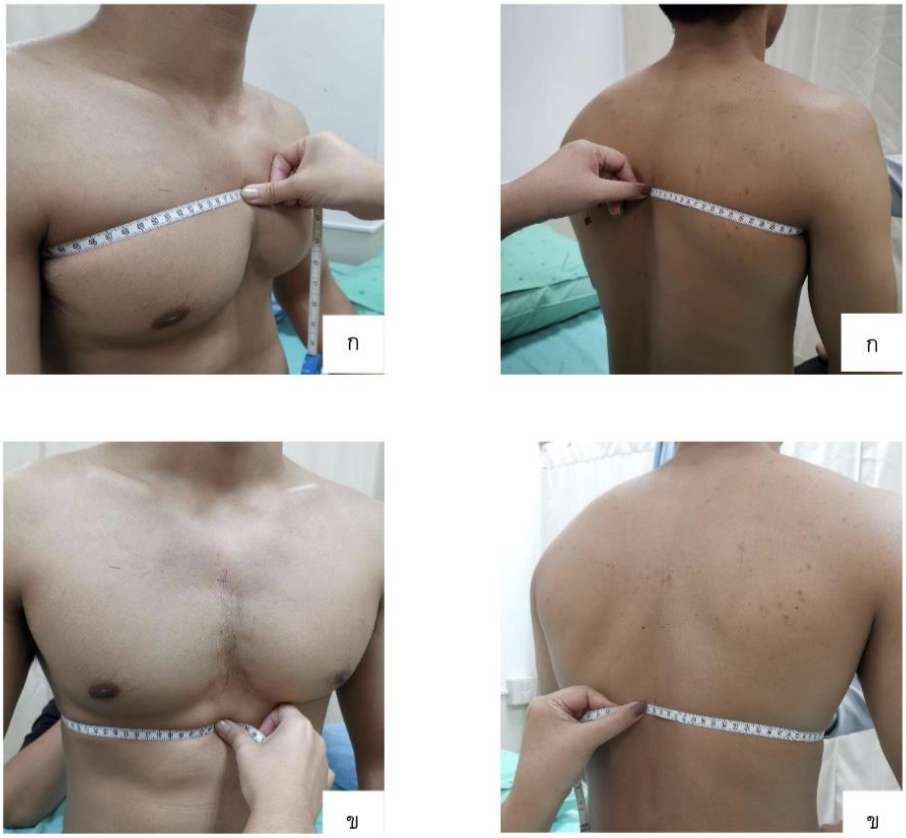
การศึกษานี้เป็นส่วนหนึ่งในการศึกษาเรื่อง ผลของการฝึกการเคลื่อนไหวทรวงอกต่อการขยายตัวของทรวงอกและอาการปวดแผลในผู้ป่วยหลังผ่าตัดกลีบปอด ซึ่งได้ผ่านการพิจารณาจากคณะกรรมการจริยธรรมเพื่อการวิจัยสถาบันโรคทรวงอก กรมการแพทย์ กระทรวงสาธารณสุข เลขที่ 038/2562

การศึกษาในครั้งนี้เป็นการศึกษาแบบภาคตัดขวาง (cross-sectional) ผู้เข้าร่วมงานวิจัยเป็นอาสาสมัครสุขภาพดีจำนวน 10 คน ไม่มีโรคทางด้านระบบทางเดินหายใจและหัวใจ ไม่มีภาวะข้อไหล่ติด และไม่เคยมีประวัติการผ่าตัดที่บริเวณทรวงอกมาก่อน อาสาสมัครทุกคนได้รับทราบวัตถุประสงค์และรายละเอียดของงานวิจัย และยินดีเข้าร่วมการวิจัยโดยการลงนามในแบบยินยอมเข้าร่วมงานวิจัย จากนั้นอาสาสมัครทั้งหมดจะได้รับการบันทึกข้อมูลพื้นฐานต่างๆ ได้แก่ เพศ อายุ ส่วนสูง น้ำหนัก และดัชนีมวลกาย อาสาสมัครอยู่ในท่านั่งหลังตรง มองตรงไปทางด้านหน้า แขนทั้งสองข้างแนบชิดกับลำตัว เท้าทั้งสองข้างวางราบกับพื้น จากนั้นผู้ประเมินคนที่ 1 จะทำการหาตำแหน่งอ้างอิงและทำเครื่องหมายไว้จำนวน 2 ตำแหน่งของทรวงอกส่วนบน ได้แก่ ด้านหน้าบริเวณช่องระหว่างกระดูกซี่โครงซี่ที่ 3 ของแนวกึ่งกลางของกระดูกไหปลาร้าและลากผ่านมาบริเวณกึ่งกลางของกระดูกหน้าอกทำสัญลักษณ์ไว้ที่ตำแหน่งนั้น และ ด้านหลังบริเวณแนวของกระดูกสันหลังส่วนอกชิ้นที่ 5 ทำสัญลักษณ์ไว้ ในส่วนของตำแหน่งอ้างอิงของการวัดการขยายตัวของทรวงอกส่วนล่าง ได้แก่ ด้านหน้าทำสัญลักษณ์ไว้ที่ลิ้นปี่ และด้านหลังทำสัญลักษณ์ไว้ที่แนวของกระดูกสันหลังส่วนอกชิ้นที่ 10 (ดังแสดงในภาพที่ 1) สำหรับผู้ประเมินคนที่ 2 จะทำการยืดตรึงสายวัดตามตำแหน่งอ้างอิงของทรวงอกทางด้านหน้าโดยไม่มีการเคลื่อนของสายวัดดังกล่าวในขณะที่อาสาสมัครหายใจ ผู้ประเมินคนที่ 1 ทำการดึงสายรัดให้แนบเนื้อและกระชับกับพื้นที่รอบทรวงอกของอาสาสมัครมากที่สุดแล้วจึงยึดตรึงสายวัดตามตำแหน่งอ้างอิงของทรวงอกทางด้านหลัง (ดังแสดงในภาพที่ 2) จากนั้นผู้ประเมินคนที่ 1 เป็นผู้สั่งให้อาสาสมัครหายใจออกเต็มที่ ผู้ประเมินคนที่ 1 เคลื่อนสายวัดไปตามการยุบตัวของทรวงอกค้างไว้ 2 วินาที บันทึกค่าที่ได้เป็นเซนติเมตร แล้วให้อาสาสมัครหายใจเข้าเต็มที่ ผู้ประเมินคนที่ 1 คลายสายวัดให้เคลื่อนไปตามการขยายตัวของทรวงอก ค้างไว้ 2 วินาที บันทึกค่าที่ได้ หลังจากนั้นให้อาสาสมัครหายใจออกปกติ อาสาสมัครจะทำการหายใจเข้า-ออกเต็มที่เป็นจำนวนทั้งหมดข้างละ 3 ครั้งทั้งทรวงอกส่วนบนและส่วนล่าง นำค่าผลต่างที่ได้ที่มากที่สุดของการหายใจเข้าและหายใจออกเต็มที่ไปวิเคราะห์ข้อมูลหาความเชื่อถือภายในของผู้วัด โดยการวัดครั้งที่ 1 และครั้งที่ 2 ห่างกันเป็นระยะเวลา 1 วัน

การทดสอบความน่าเชื่อถือภายในของผู้วัด (Intra-rater reliability) ใช้สถิติ Intraclass correlation coefficient: ICC (3,1) โดยใช้โปรแกรม SPSS กำหนดค่า ICC <0.5 เป็นความน่าเชื่อถือในระดับน้อย ICC เท่ากับ 0.5 ถึง <0.75 เป็นความน่าเชื่อในระดับปานกลาง ICC เท่ากับ 0.75 ถึง <0.9 เป็นความน่าเชื่อถือในระดับดี และ ICC $\geq$0.9 เป็นความน่าเชื่อถือในระดับดีมาก [4] และกำหนดระดับสำคัญทางสถิติที่ p <0.05



ภาพที่ 1 ตำแหน่งอ้างอิงของการวัดการขยายตัวของทรวงอกส่วนบนและส่วนล่างทั้งทางด้านหน้าและด้านหลัง



ภาพที่ 2 วิธีวัดการขยายตัวของทรวงอกแบบครึ่งรอบทรวงอกของทรวงอกส่วนบน (ก) และทรวงอกส่วนล่าง (ข)

ผลการวิจัย

อาสาสมัครจำนวนทั้งสิ้น 10 คน ประกอบด้วยเพศหญิงจำนวน 6 คนและเพศชายจำนวน 4 คน อายุเฉลี่ย 30.0±1.6 ปี และดัชนีมวลกายเฉลี่ย 23.9±4.1 กิโลกรัม/ตารางเมตร ดังแสดงในตารางที่ 1

ตารางที่ 1 ข้อมูลพื้นฐานของอาสาสมัคร

ตัวแปร	ค่าเฉลี่ย±ส่วนเบี่ยงเบนมาตรฐาน
เพศ ชาย/หญิง (คน)	4/6
อายุ (ปี)	30.0±1.6
น้ำหนัก (กิโลกรัม)	64.2±14.9
ส่วนสูง (เซนติเมตร)	163.5±9.1
ดัชนีมวลกาย (กิโลกรัม/ตารางเมตร)	23.9±4.1

ผลการศึกษาพบว่าความน่าเชื่อถือภายในของผู้วัดมีความน่าเชื่อถืออยู่ในระดับดีมาก ในการวัดการขยายตัวของทรวงอกส่วนบนและส่วนล่างทั้ง 2 ข้าง ค่า ICC ของการขยายตัวของทรวงอกทางด้านซ้ายและขวาของทรวงอกส่วนบนเท่ากับ 0.92 และ 0.98 ตามลำดับ ส่วนค่า ICC ของการขยายตัวของทรวงอกทางด้านซ้ายและขวาของทรวงอกส่วนล่างเท่ากับ 0.93 และ 0.91 ตามลำดับ ดังแสดงในตารางที่ 2

ตารางที่ 2 ค่าความน่าเชื่อถือภายในของผู้วัดการขยายตัวของทรวงอกส่วนบนและส่วนล่าง

การขยายตัวของทรวงอก	ครั้งที่ 1 (เซนติเมตร) ค่าเฉลี่ย±ส่วนเบี่ยงเบนมาตรฐาน	ครั้งที่ 2 (เซนติเมตร) ค่าเฉลี่ย±ส่วนเบี่ยงเบนมาตรฐาน	ICC (3,1) (ช่วงความเชื่อถือ 95%)	p-value
ส่วนบนทางด้านซ้าย	1.3±0.3	1.2±0.3	0.92 (0.71-0.98)	<0.001
ส่วนบนทางด้านขวา	1.2±0.3	1.2±0.3	0.98 (0.73-0.98)	<0.001
ส่วนล่างทางด้านซ้าย	1.4±0.4	1.3±0.4	0.93 (0.75-0.98)	<0.001
ส่วนล่างทางด้านขวา	1.3±0.4	1.3±0.4	0.91 (0.67-0.98)	<0.001

อภิปรายผลการวิจัย

การศึกษานี้มีวัตถุประสงค์เพื่อศึกษาความเชื่อถือภายในของผู้วัดในการวัดการขยายตัวของทรวงอกโดยใช้สายวัดแบบครึ่งรอบทรวงอกในอาสาสมัครที่มีสุขภาพดี จากการศึกษาพบว่าการวัดการขยายตัวของทรวงอกทั้ง 2 ข้างในส่วนของทรวงอกส่วนบนและส่วนล่างมีความเชื่อถืออยู่ในระดับดีมาก การศึกษาที่ผ่านมาเป็นการวัดเส้นรอบวงรอบทรวงอกในอาสาสมัครที่มีสุขภาพดีซึ่งได้ค่าความเชื่อถือภายในของผู้วัดอยู่ในเกณฑ์ระดับดี-ดีมาก (ICC เท่ากับ 0.81-0.96) [2, 3, 5] จึงทำให้การวัดการขยายตัวของทรวงอกด้วยสายวัดได้รับการยอมรับและนำมาใช้ในการตรวจประเมินการขยายตัวของทรวงอกในผู้ป่วย จากการศึกษาครั้งนี้พบว่าการวัดแบบครึ่งรอบทรวงอกก็ให้ความน่าเชื่อถือภายในของผู้วัดที่สูงเช่นกัน ผู้วิจัยจึงมีความมั่นใจในการนำวิธีการวัดการขยายตัวของทรวงอกด้วยสายวัดแบบครึ่งรอบทรวงอกนี้ไปใช้ในการตรวจประเมินผู้ป่วยผ่าตัดปอดต่อไป

สำหรับผลรวมของการขยายตัวแบบครึ่งรอบทรวงอกทั้ง 2 ข้างในส่วนบนมีค่าประมาณ 2.4-2.5 เซนติเมตร และส่วนล่างมีค่าประมาณ 2.6-2.7 เซนติเมตร ซึ่งส่วนบนได้ค่าใกล้เคียงกับการศึกษาของปรียาภรณ์ สองศรและคณะ (2014) ที่ศึกษาการขยายตัวของทรวงอกแบบเส้นรอบวงโดยใช้สายวัดในคนไทยช่วงอายุ 20-39 ปี ทั้งเพศหญิงและเพศชายพบว่ามีค่าระหว่าง 2.03 ถึง 2.97 เซนติเมตร [6] และการศึกษาของเสาวนีย์ เหลืองอร่ามและคณะ (2012) ที่ศึกษาในคนไทยเพศชายอายุระหว่าง 18-23 ปี พบว่ามีค่าการขยายตัวของทรวงอกส่วนบนเท่ากับ 2.88 เซนติเมตร [7] ส่วนการขยายตัวของทรวงอกส่วนล่างในการศึกษาครั้งนี้มีค่าน้อยกว่าการศึกษาที่ผ่านมาที่พบว่าการขยายตัวของทรวงอกส่วนล่างนี้มีค่าตั้งแต่ 3.64 ถึง 5.13 เซนติเมตร ทั้งนี้อาจเนื่องมาจากการศึกษาครั้งนี้มีกลุ่มตัวอย่างมีจำนวนน้อย การศึกษาที่ผ่านมาใช้กลุ่มตัวอย่างจำนวน 100 คน [7] และ 400 คน [6] รวมทั้งการศึกษาของเสาวนีย์ เหลืองอร่ามและคณะ (2012) ได้ศึกษาเฉพาะในกลุ่มเพศชายจึงทำให้ค่าการขยายตัวของทรวงอกมีค่ามากกว่าการศึกษาในครั้งนี้ เนื่องจากเพศชายมีความแข็งแรงของกล้ามเนื้อหายใจและมวลกล้ามเนื้อรอบทรวงอกมากกว่าในเพศหญิง ส่งผลให้มีการขยายตัวของทรวงอกมากกว่าเพศหญิง [6]

ในการศึกษาครั้งนี้ใช้ผู้ประเมินทั้งหมด 2 คน โดยผู้ประเมินคนหนึ่งทำการยึดตรึงสายวัดด้านหนึ่งให้อยู่กับที่ ทำให้ผู้ประเมินอีกคนหนึ่งสามารถควบคุมการเคลื่อนของสายวัดได้อย่างแม่นยำ ส่งผลให้ค่าการวัดการขยายตัวของทรวงอกมีความน่าเชื่อถือและลดความคลาดเคลื่อนในการวัด ความผิดพลาดของข้อมูลจึงเกิดน้อยที่สุด อย่างไรก็ตามการนำไปใช้ทางคลินิกอาจเกิดข้อจำกัดทางด้านบุคลากร

สรุปผลการวิจัย

การวัดการขยายตัวของทรวงอกแบบครึ่งรอบทรวงอกในการศึกษาครั้งนี้มีความน่าเชื่อถือภายในของผู้วัดอยู่ในเกณฑ์ระดับดีมากทั้งทรวงอกส่วนบนและส่วนล่างทั้ง 2 ข้าง ดังนั้นจึงมีความมั่นใจในการนำไปใช้ในงานวิจัยเกี่ยวกับการประเมินการเปลี่ยนแปลงของการขยายตัวของทรวงอกในการศึกษาครั้งต่อไป

กิตติกรรมประกาศ

คณะผู้วิจัยขอขอบคุณมหาวิทยาลัยศรีนครินทรวิโรฒที่ได้ให้ทุนสนับสนุนงานวิจัยในครั้งนี้ ขอบคุณงานกายภาพบำบัดระบบทางเดินหายใจและปอด สถาบันโรคทรวงอกที่อนุเคราะห์สถานที่ในการวิจัย ผู้ช่วยนักวิจัยและอาสาสมัครทุกท่านที่ให้ความร่วมมือและกรุณาสละเวลาอันมีค่าในการเข้าร่วมการศึกษาวิจัย

เอกสารอ้างอิง

[1] Elshafie, Ghazi; Kumar, Prem; Motamedi-Fakhr, Shayan; Iles, Richard; Wilson, Rachel C.; and Naidu, Babu. (2016, April). Measuring changes in chest wall motion after lung resection using structured light plethysmography: a feasibility study. *Interac Cardiovasc Thorac Sur.* 23: 544-547.

[2] Bockenhauer, Susan E.; Chen, Haifan; Julliard, Kell N.; and Weedon, Jeremy. (2007, May). Measuring thoracic excursion: Reliability of the cloth tape measure technique. *J Am Osteopath Assoc.* 107*(5):* 191-196.

[3] Debouche, Sophie; Pitance, Laurent; Robert, Annie; Liistro, Giuseppe; and Reychler, Gregory. (2016, January). Reliability and reproducibility of chest wall expansion measurement in young healthy adults. *J Manipulative Physiol Ther.* 39: 443-449.

[4] Leslie G Portney.; and Mary P. Watkins. (2000). *Foundations of clinical research: applications to practice*. 3rd ed. New Jersey: Prentice Hall Health.

[5] Lapier, Tanya K.; Cook, Adrain; Droege, Karoline; Oliverson, Rachello; Rulon, Ryan; Stuhr, Elzabeth; Yates, Daniel; and Devine, Nancy. (2000, September). Intertester and intratester reliability of chest excursion measurement in subjects without impairment. *Cardiopulmonay Phys Ther*. 11(3): 94-98.

[6] ปรียาภรณ์ สองศร, จุฑารัตน์ อริยะวงศ์ทอง, อังคณา เกณฑ์สาคู. (2014, ตุลาคม-ธันวาคม). ค่าอ้างอิงของการขยายตัวของทรวงอกในประชากรไทยสุขภาพดี อายุ 20-70 ปี. *ธรรมศาสตร์เวชสาร*. 14(4): 571-579.

[7] เสาวนีย์ เหลืองอร่าม, ทวีสุข ผ้ายก๊ก, ดวงเดือน สินธุชัย, สุวิภา แก้วเกิด. (2012, พฤษภาคม-สิงหาคม). การขยายตัวของทรวงอกในชายไทยสุขภาพดี อายุ 18-23 ปี ในจังหวัดพิษณุโลก: การศึกษานำร่อง. *วารสารการพยาบาลและสุขภาพ*. 6(2): 56-61.

APPENDIX D

DATA COLLECTING FORM

เลขที่.....

แบบบันทึกการเก็บข้อมูลวิจัย

<u>ส่วนที่ 1: ข้อมูลทั่วไป</u>

ชื่อ-นามสกุล..... อายุ.....ปี

HN:..... เพศ ☐ ชาย ☐ หญิง น้ำหนัก.....กก.

ส่วนสูง.....ซม. BMI.....kg/m^2

โรคประจำตัว ☐ ความดันโลหิตสูง ☐ ไขมันในเลือดสูง ☐ เบาหวาน ☐ โรคหัวใจ ☐ โรคไต ☐ อื่น ๆ โปรดระบุ.....

ประวัติการสูบบุหรี่ (ถ้าเคยสูบบุหรี่ โปรดระบุข้างล่าง) ☐ เคย ☐ ไม่เคย

ปัจจุบันท่านยังสูบบุหรี่หรือไม่ ☐ หยุดแล้ว ☐ ยังสูบอยู่ ระบุ.....มวน/วัน .....ซอง/ปี

สมรรถภาพปอดก่อนการผ่าตัด (ถ้ามี) ☐ Normal ☐Obstruction ☐ Restriction

- FEV1/FVC.....%
- FVC..... L .....%, FEV1..... L .....%,
- FEF25-75..... L .....%, PEF..... L .....%,

<u>ส่วนที่ 2. เกณฑ์คัดเข้าและเกณฑ์คัดออกของอาสาสมัครในโครงการวิจัย</u>

เกณฑ์การคัดเข้าของอาสาสมัครในโครงการวิจัย (Included: total 3 items)

☐ Age $\geq$ 18 years old

☐ Elective pulmonary resection at CCIT

☐ Undergoing lobectomy

เกณฑ์การคัดออกของอาสาสมัครในโครงการวิจัย (Excluded: only 1 item)

☐ Unable to participation

☐ Hemoptysis

☐ Underlying disease following post cardiac surgery, COPD and restriction lung disease such as interstitial pulmonary disease, scoliosis

☐ Limitation of shoulder range of motion

☐ Receive respiratory physiotherapy within 2 weeks prior to surgery

☐ On mechanical ventilator more than 24 hours after surgery

☐ Hemodynamic instability within 1st postoperatively

☐ Postoperative complications of chylothorax and severe air leak (air leak prolong time during inspiration and expiration)

ส่วนที่ 3: ข้อมูลหลังการผ่าตัด

- Operative date…….. D/C date…….…….. LOS…….. days Dx:……..……

- Technique: ☐VATs ☐Thoracotomy ☐ Mini-thoracotomy

- Type: ☐ RUL ☐ RML ☐ RLL ☐ LUL ☐ LLL ☐Other……

- Day when all day ICD remove: date……/……/…….. total……days

- Complication ☐ Pneumonia ☐ Atelectasis ☐ Pneumothorax ☐ ARDS
☐Plural effusion ☐ Reintubation ☐Other…….

ส่วนที่ 4: ข้อมูล V/S, CE, pain score and 6MWD ก่อนผ่าตัด วันที่ 1-6 หลังผ่าตัด ก่อนกลับบ้านและ 2 สัปดาห์หลังจากกลับบ้าน

ก่อนผ่าตัด Date……/……/…….. V/S:HR……..bpm BP…….mmHg SpO_2……%

- Pain score……
- 6MWD……..m. (HR……..bpm BP……..mmHg SpO_2…….% RPD…..)

	Rt.			Lt.		
Upper CE						
Lower CE						

วันที่ 1 หลังผ่าตัด Date……/……/……..

- V/S: HR……..bpm BP……/……mmHg SpO_2……%
- Pain score……

	Rt.			Lt.		
Upper CE						
Lower CE						

<u>วันที่ 2 หลังผ่าตัด</u> Date……/……/……..

- V/S: HR……..bpm BP……/…….mmHg SpO_2…….%
- Pain score…….

	Rt.			Lt.		
Upper CE						
Lower CE						

<u>วันที่ 3 หลังผ่าตัด</u> Date……/……/……..

- V/S: HR……..bpm BP……/…….mmHg SpO_2…….%
- Pain score…….

	Rt.			Lt.		
Upper CE						
Lower CE						

<u>วันที่ 4 หลังผ่าตัด</u> Date……/……/……..

- V/S: HR……..bpm BP……/…….mmHg SpO_2…….%
- Pain score…….

	Rt.			Lt.		
Upper CE						
Lower CE						

<u>วันที่ 5 หลังผ่าตัด</u> Date……/……/……..

- V/S: HR……..bpm BP……/…….mmHg SpO_2…….%
- Pain score…….

	Rt.			Lt.		
Upper CE						
Lower CE						

<u>วันที่ 6 หลังผ่าตัด</u> Date……/……/……..

- V/S: HR……..bpm BP……/…….mmHg SpO_2…….%
- Pain score…….

	Rt.			Lt.		
Upper CE						
Lower CE						

<u>ก่อนกลับบ้าน</u> Date……/……/……..

- V/S: HR……..bpm BP……/…….mmHg SpO_2…….%
- Pain score…….
- 6MWD……..m. (HR……..bpm BP……mmHg SpO_2…….% RPD…..)

	Rt.			Lt.		
Upper CE						
Lower CE						

APPENDIX E

RAW DATA OF UPPER CHEST EXPANSION

NO.	Group	Operated side				Non-operated side			
		UCE-P	UCE-1	UCE-2	UCE-3	UCE-P	UCE-1	UCE-2	UCE-3
1	C	1.3	0.3	0.6	0.8	1.1	0.5	1.0	0.6
2	E	1.7	0.9	1.5	1.1	1.6	1.5	2.0	1.8
3	C	2.0	1.3	1.5	1.3	1.5	1.0	2.0	1.6
4	C	1.0	0.8	0.8	0.8	1.3	1.1	1.1	1.5
5	E	1.8	0.7	1.3	1.5	2.2	0.7	1.7	1.7
6	E	2.0	1.1	1.3	1.2	2.2	1.5	1.3	1.7
7	C	2.0	1.1	1.5	1.7	2.6	1.0	1.6	1.6
8	C	1.3	0.7	0.7	0.8	1.5	1.1	1.3	1.8
9	E	1.8	0.5	1.2	1.4	1.8	0.5	1.2	1.4
10	E	2.1	1.5	1.2	1.1	2.1	1.0	1.6	1.7
11	E	1.5	1.1	1.1	1.0	1.3	0.7	1.3	1.1
12	C	1.8	0.5	0.5	0.5	1.8	0.5	0.5	0.6
13	C	1.6	1.1	1.6	1.5	1.7	2.0	2.2	1.8
14	E	2.0	1.7	1.6	1.8	2.5	2.4	2.7	2.5
15	C	1.5	1.0	0.9	0.8	1.5	1.2	1.5	1.2
16	E	3.2	0.8	0.8	1.7	3.0	1.2	1.5	1
17	C	1.8	1.0	0.7	1.0	2.2	1.2	1.5	1.8
18	C	2.0	0.7	0.9	1.2	1.6	1.0	1.0	1.5
19	E	1.9	0.8	1.0	0.9	1.5	1.5	1.4	1
20	E	2.0	1.0	1.3	1.3	1.4	1.3	1.4	1.4
21	E	3.0	1.1	1.5	2	2.4	1.4	2.2	2.5
22	C	1.8	0.7	0.9	1.3	1.4	1.2	1.4	1.6
23	C	1.6	1.0	1.1	1.4	1.8	1.5	1.2	1.4
24	E	1.7	1.1	1.5	1.6	1.8	1.2	1.5	2.2
25	E	2.0	1.0	1.2	0.7	2.0	1.5	1.6	1.3
26	C	2.5	0.6	1.2	1.2	2.7	1.1	1.3	1.7

NO.	Group	Operated side				Non-operated side			
		UCE-P	UCE-1	UCE-2	UCE-3	UCE-P	UCE-1	UCE-2	UCE-3
27	C	2.2	1.0	1.0	1.1	1.6	1.0	1.4	1.3
28	E	2.4	1.3	1.5	2.0	2.2	1.6	1.5	2.0
29	C	2.8	1.0	1.4	1.7	2.5	1.5	1.8	2.0
30	C	2.5	1.5	1.7	1.8	2.3	1.9	2.0	2.2
31	E	2.5	1.3	1.4	2.0	2.8	1.8	1.9	2.3
32	C	2.6	1.4	2.5	2.1	2.1	1.5	2.8	2.4
33	E	2.6	1.0	1.4	1.5	2.4	1.0	2.0	1.9
34	E	3.0	2.2	2.0	2.7	3.0	3.0	3.0	3.7
35	C	3.0	0.7	1.3	1.2	2.9	1.5	2.3	2.3
36	E	3.0	1.3	2.0	2.0	2.7	2.0	2.3	2.8

APPENDIX F

RAW DATA OF LOWER CHEST EXPANSION

NO.	Group	Operated side				Non-operated side			
		LCE-P	LCE-1	LCE-2	LCE-3	LCE-P	LCE-1	LCE-2	LCE-3
1	C	1.8	0.5	0.8	0.5	1	0.9	1	0.9
2	E	1.8	1.1	1.2	1.4	2.1	1.6	1.6	1.5
3	C	2.4	1	1.9	1.2	1.5	1.2	1.6	1.7
4	C	1.6	0.6	0.5	0.8	0.8	1.2	1.3	1.4
5	E	2.3	0.6	1.2	1.2	1.9	1.8	1.8	1.7
6	E	2.2	0.7	0.6	0.7	2.2	1.6	1.6	1.6
7	C	2.2	1.3	1.3	1	2.9	1.2	2	2
8	C	1.5	0.6	0.6	0.6	1.6	0.8	1.2	1.3
9	E	2	0.4	1.3	1	2	0.4	1.2	1
10	E	2	0.8	1	1	2	1.2	1.4	1.8
11	E	2.1	1.2	0.9	1.1	1.3	0.6	1.4	1.2
12	C	2	0.5	0.4	0.4	2	0.5	0.4	0.4
13	C	1.7	1	1.2	1.6	1.8	1.4	1.8	2.2
14	E	1.5	1.3	1.7	1.9	2.2	1.9	2	2.3
15	C	1.3	0.8	1.1	1	1.6	0.9	1.4	1.5
16	E	4	0.8	0.8	1	4	1.5	1.6	2.1
17	C	2.8	0.6	1	1	2.4	1.1	1.1	1.6
18	C	2.1	0.8	1	1.3	1.8	1.2	1.3	1.5
19	E	2.1	1	1	0.6	1.6	1.2	1.5	1.5
20	E	1.8	1.3	1.3	1.4	2	1.4	1.4	1.4
21	E	3.1	1.2	1.3	2	3	2	2.2	2.9
22	C	2.4	1	1.1	1.5	2.3	1.5	1.6	1.7
23	C	1.8	1.3	1.2	1.5	1.7	1.2	1.1	1.4
24	E	2	0.7	1.4	1.3	1.7	1.1	1.6	2
25	E	2.5	1.2	1.5	1.2	2	1.5	1.7	2
26	C	2.9	0.6	1.3	1.5	3	1.2	1.5	1.7
27	C	2.5	0.7	1.1	1.1	1.8	1.4	1.5	1.7

NO.	Group	Operated side				Non-operated side			
		LCE-P	LCE-1	LCE-2	LCE-3	LCE-P	LCE-1	LCE-2	LCE-3
28	E	3.2	1.5	1.8	2.1	2.5	1.8	2	2.1
29	C	2.7	1.4	1.4	1.6	3	1.7	1.5	2.1
30	C	2.5	1.4	1.5	2	2.5	1.6	1.7	2.2
31	E	3	1.3	1.3	2	3	2.2	2.2	2.3
32	C	3.1	1.5	2.2	2.3	3.1	2	3	3
33	E	2.7	0.6	2	1.4	2.6	1.1	2	2
34	E	2.5	3	2.5	3.5	3.1	3.2	3	4.5
35	C	3	0.6	0.9	0.9	3.1	1.7	2.5	2.8
36	E	3.4	2	1.9	2.7	3	2.2	2.1	3

APPENDIX G

RAW DATA OF PAIN SCORE

NO.	Group	Pre-op	Day 1	Day 2	Day 3
1	C	0	5	5	4
2	E	0	5	5	5
3	C	0	2	2	2
4	C	0	3	3	2
5	E	0	6	6	5
6	E	0	8	8	6
7	C	0	5	5	2
8	C	0	6	6	5
9	E	0	3	3	2
10	E	0	5	3	3
11	E	0	3	5	3
12	C	0	5	5	4
13	C	0	4	4	1
14	E	0	7	7	5
15	C	0	5	5	4
16	E	0	7	7	6
17	C	0	3	3	3
18	C	0	5	5	4
19	E	0	5	5	3
20	E	0	5	5	3
21	E	0	8	8	6
22	C	0	7	5	4
23	C	0	5	4	4
24	E	0	5	3	3
25	E	0	5	5	2
26	C	0	10	10	4
27	C	0	8	8	5
28	E	0	0	0	0

NO.	Group	Pre-op	Day 1	Day 2	Day 3
29	C	0	5	4	4
30	C	0	8	8	5
31	E	0	5	5	4
32	C	0	5	5	3
33	E	0	5	5	5
34	E	0	2	1	0
35	C	0	6	6	5
36	E	0	5	5	5

APPENDIX H

RAW DATA OF SIX-MINUTE WALK DISTANCE

NO.	Group	Preoperative day	Postoperative day
1	C	390	175
2	E	490	271
3	C	505	471
4	C	450	412
5	E	475	471
6	E	523	400
7	C	562	560
8	C	430	333
9	E	507	438
10	E	439	324
11	E	275	278
12	C	515	375
13	C	400	395
14	E	660	475
15	C	250	265
16	E	516	439
17	C	545	511
18	C	379	275
19	E	385	335
20	E	281	280
21	E	445	395
22	C	375	375
23	C	200	175
24	E	425	400
25	E	457	572
26	C	370	377

NO.	Group	Preoperative day	Postoperative day
27	C	500	315
28	E	411	383
29	C	341	273
30	C	556	495
31	E	455	363
32	C	400	412
33	E	360	305
34	E	397	500
35	C	355	325
36	E	487	325

VITA

NAME	NAPAPORN VAEWTHONG
DATE OF BIRTH	12 JUNE 1988
PLACE OF BIRTH	RATCHABURI
INSTITUTIONS ATTENDED	SRINAKHARINWIROT UNIVERSITY
HOME ADDRESS	46/3 TIWANON ROAD, T. BANGKASOR, A.MUANG, NONTHABURI 11000