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Review Article

Breathe Stronger, Walk Farther: Inspiratory Muscle Training Post Lung Resection Surgery A Systematic Review

Sana Shahzad, Ayesha Sonia, Danish Zaman, Saima Ali, Hamza Ahmed*, Muhammad Haris Raza

Department of Physical Therapy, Ziauddin College of Physical Therapy, Karachi Pakistan,
*Department of Physical Therapy, United College of Physical Therapy, Karachi Pakistan

ABSTRACT

Objective: To assess the efficacy of Inspiratory Muscle Training (IMT) on functional exercise capacity and pulmonary functions using the six-minute walk test and spirometry in patients undergoing lung resection surgery.
Study Design: Systematic review.
Methodology: Randomized controlled clinical trials (RCTs) were selected from four databases, including Google Scholar, PEDro, Cochrane Library, and PubMed. Two reviewers independently assessed the studies' quality. Eight randomized controlled trials examined the effectiveness of IMT on pulmonary functions and functional exercise capacity following lung resection surgeries.
Results: High-to-moderate evidence shows that inspiratory muscle training is effective in improving functional exercise capacity and pulmonary functions post-operatively in patients with lung resection surgery.
Conclusion: The conclusions of this systematic review indicated that postoperative inspiratory muscle training, either administered alone or in conjunction with other combined interventions, improved patients' functional pulmonary capacity and further enhanced other outcomes, such as physical activity and muscle strength.

Keywords: Six-Minute Walk Test, Respiratory Function Test, Respiratory Muscle Training, Post-Lung Resection Surgery.

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INTRODUCTION

Around the world, lung cancer is the most common cause of cancer-related mortality, accounting for the majority of deaths in both men and women. Lung cancer is a serious illness that has the potential to cause significant damage or be fatal. WHO reported[1] 5 million new cases of lung cancer in 2020. According to the Centers for Disease Control and Prevention, the management of lung cancer may include targeted therapy, chemotherapy, radiation therapy, surgery, or a cocktail of these treatments. Lung resection is the surgical removal of part or all of the lung. It is a viable approach that is linked with a better outcome.[2] Lung resection is a broad term that includes procedures such as Lobectomy - when one of the five lobes is removed; Segmentectomy - when a segment is removed; Wedge resection - when a small section of the lung is removed; and Pneumonectomy- when an entire lung is removed. A complete lymph node dissection is also performed.[3] Pulmonary resection is associated with long-term survival and should remain a therapeutic option in oligometastatic lung cancer.[4]

Correspondence: Dr Sana Shahzad, Department of Physical Therapy, Ziauddin College of Physical Therapy Karachi Pakistan
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A consequence of surgeries in the thoracic region is the post-surgical respiratory complications that may occur due to the intraoperative mechanical ventilation reported by Uhlig *et al.*, 2020. To address these complications, generally, exercises are recommended.[3] Peddle *et al.*, 2019 stated that exercise is an essential aspect of the regime of lung cancer treatment. Exercise training improves exercise capacity and quality of life in adults with advanced forms of lung cancer. Complications after lung surgery that patients usually suffer from include weak respiratory muscles, impaired pulmonary function, and shortness of breath. One of the effective ways to deal with these postoperative complications is training muscles responsible for respiration.[4] As quoted in a narrative review by Ahmad *et al.*, in 2018 chest physical therapy effectively reduces post-lung resection pulmonary complications.[5] Pulmonary rehabilitation with physical manipulation has enhanced lung function and reduced postoperative chest drainage time and hospital stay.[6] Focused lung rehabilitation programs are evident in enhancing pulmonary efficiency in patients who endured lung respective surgeries, such as alleviating symptoms of dyspnea and enhancing self-esteem.[7,8] Respiratory muscle training is a form of intervention that mainly focuses on strengthening the muscle of

respiration, particularly inspiratory muscle training (IMT). IMT is a form of strength training that targets respiratory muscles, their strength, and function and helps reduce dyspnea.[9] Lähteenmäki *et al*., in 2020 concluded that IMT is an easier and safer therapy during the postoperative span and has good pulmonary function test outcomes.[10] Enhancing exercise capacity and lung function is crucial to boost patients' functional status and quality of life after surgery. Identifying the potential benefits of IMT could help guide based on research, ultimately improving patient outcomes and saving healthcare costs because optimizing lung function and exercise capacity after surgery is crucial.

While individual studies have looked into different aspects of IMT, a systematic review of the available evidence is required to determine the effectiveness of this intervention on key outcomes such as lung function and exercise capacity in the post-surgical management of patients who underwent resection surgeries such as Lobectomy. Hence, this study will highlight the potential gaps in the literature and guide future clinical practice to achieve optimal patient recovery.

METHODOLOGY

In the systematic review PRISMA's guidelines (Preferred Reporting Items for Systematic Review and Meta-analysis) were used (Figure).[11]

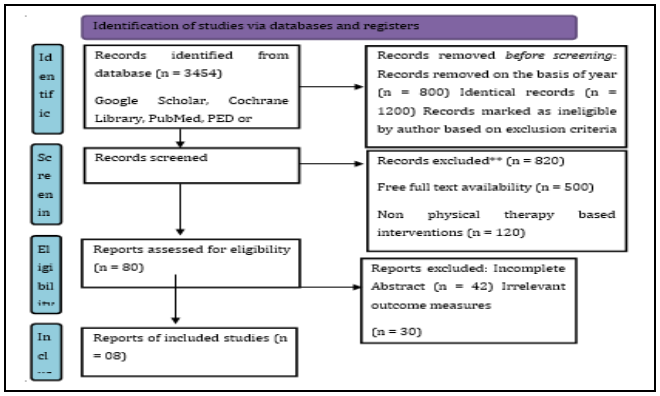

Figure: PRISMA Flow Diagram

Databases and Literature Surveillance

Two independent researchers conducted a search strategy from August 2023 to November 2023 using the following electronic databases: Google Scholar, Pubmed, Cochrane Library, and PEDRro for the articles published between 2018 and 2023. The Search keywords from Mesh were "Inspiratory Muscle Training," "Lung Resection," 'Lobectomy" and "Randomized Controlled Trial," which were combined with Boolean operators (and and or); "Inspiratory Muscle Training" and "Lobectomy" and "Randomized Controlled Trial," "Inspiratory Muscle Training" and "Lung Resection" or "Lobectomy" and "Randomized Controlled Trial."

Eligibility Criteria

The included studies were selected using the PIODS approach, which stands for Population, Intervention, Outcomes, Design, and Setting. Moreover, the inclusion criteria were: studies that used inspiratory muscle training as a primary intervention after lung resection or lobectomy; few studies included in this study that provide one-day pre-operative physical therapy, incentive spirometry (to measure pulmonary function) and 6-minute walk test (to measure exercise capacity) were the primary outcome measures of included studies. Randomized controlled trials published during the year July 2018-April 2023 were included in this study. Studies not available in English or without translation versions were excluded. Reported data was unable to analyze specifically the pulmonary functions and exercise capacity. Studies are excluded if full text or duplication is unavailable and if that study is conducted before 2018.

Data Extraction

The data extraction process was done according to the checklist and Cochrane guidelines. The following information has been extracted from the selected studies: 1) author and publication year, 2) participants' characteristics (number of participants, gender, age), 3) research design, 4) type and characteristics of interventions, and 5) assessed outcome measures and 6) summary of results and 7) study setting[12].

Two independent reviewers completed all the steps of data extraction. However, in case of disagreement regarding study selection and data extraction, three, four, and five reviewers intervened and solved the problem with the consensus of all.

Risk of Bias

The risk of bias in random allocation, allocation concealment, participant and assessor blinding, attrition bias, selective reporting, and other potential biases (conflict of interest, funding, etc.) was assessed using the Cochrane tool (Table-I).[13-17]

Table-I: Risk of Biasness

S. No	Author and year of publication	Random sequence Generation	Allocation concealment	Performance Bias/ Blinding of participants and personnel	Detection Bias / Blinding of outcome assessor	Attriation Bias /Incomplete Outcome Data	Selective Reporting	Other Bias
1	Duc M. Ha, 2023	+	+	-	+	-	+	+
2	Filipa Kendall, 2020	+	-	?	?	+	+	+
3	Harun Taşkin, 2018	+	+	+	+	-	+	+
4	Jui-Fang Liu, 2020	+	+	+	+	-	+	+
5	Monique, 2019	+	+	+	?	-	+	-
6	Nai-Ying Kuo, 2022	+	+	+	+	+	+	-
7	Sabina Lähteenmäki, 2020	+	-	-	?	+	+	+
8	Sabina Lähteenmäki, 2021	+	+	-	+	+	+	+
+ sign shows high risk of biasness			- sign shows low risk of biasness			? shows some concerns/ incomplete data given.		

Interventions and Outcome Measures

Ha *et al.*,[13] demonstrated significant improvements in physical activity and functional exercise capacity following IMT through a pilot randomized trial. Kuo *et al.*,[18] reported dramatic improvements in exercise capacity and respiratory function after a home-based rehabilitation program, including IMT.

Lähteenmäki[10] and Lähteenmäki[19] both found significant increases in VO_2 peak and respiratory muscle strength with IMT interventions and VO_2 peak. Liu *et al.*,[16] in 2020 demonstrated enhanced aerobic activity and respiratory muscle strength following surgery with IMT. Kendall *et al*[14] highlighted the benefits of combining IMT with traditional physiotherapy, showing improvements in inspiratory muscle strength and physical activity.

Monique *et al.*,[17] in 2019 and Taşkin *et al.*,[15] in 2018 also reported improvements in respiratory muscle strength and exercise capacity following IMT interventions. Tao *et al.*,[20] 2024, conducted a randomized controlled trial focusing on thoracoscopic lobectomy patients, showing significant increases in VO_2 peak and respiratory muscle strength with personalized pulmonary rehabilitation exercise training.

Based on the findings from these trials, IMT is an effective technique for improving exercise tolerance, respiratory health, and physical activity in individuals who have survived lung cancer. It appears that IMT breaks the "dyspnea-inactivity" loop and enhances patients' ability to engage in physical activity by strengthening respiratory muscles and improving aerobic capacity. Regarding VO_2 peak, IMT therapies have continuously produced positive outcomes. Standard of living, exercise capacity, and pulmonary muscular endurance are a few more end-measure indices.

Additionally, IMT therapies have shown promise both before and after surgery, indicating that they might enhance patients' recuperation and outcomes from rehabilitation who are having surgery for lung cancer.

The range of interventions employed in the research demonstrates that IMT is adaptable and workable in several therapeutic contexts. These interventions include combination rehabilitation techniques, home-based programs, and specific interventions specific to specific surgery groups. Further research is required to standardize IMT procedures, look into long-term outcomes, and determine the best duration and timing of IMT interventions.

DISCUSSION

This review involved comprehensive literature searches and reviews. The study's features were then collected and reviewed to assess and evaluate them. The total number of patients in all studies was 345, with 156 individuals in the interventional group receiving Inspiratory Muscle Training (IMT) (Table-II).

The reported studies demonstrate the effectiveness of inspiratory muscle training (IMT) in enhancing physical activity, respiratory muscle strength, and exercise capacity in patients recovering from lung cancer surgery. In a trial by Ha *et al*.,[13] IMT combined with walking significantly improved physical activity and functional exercise capacity in lung cancer survivors over 12 weeks, while the control

Table-II: Evidence Table.

Authors & Year	Sample Size	Target population	Group	Intervention	Outcome Measure
Duc M.Ha 2023	n=28	Lung cancer survivors	EG	Exercise Training (IMT+Walking), Education And Behavior Change Support.	1. Physical Activity (Activpal™ Steps/Day) 2. Functional Exercise Capacity (Mobile Based-Six-Minute-Walk-Test),
			CG	Participants Received Educational Materials on General Exercise	
Nai-Ying Kuo 2022	n=36	Patients with lung tumors who underwent video-assisted thoracoscopic surgery (VATS).	EG	(1) Breathing Exercises And Coughing Exercises, (2) Aerobic Exercises (3) Incentive Spirometry Training (4) Threshold Load Training Of The Inspiratory Muscle.	1. 6-Minutes Walking Test 2. Forced Vital Capacity (Fvc), Forced Expiratory Volume In 1 Second (Fev1) Using Spirometry
			CG	Pain Medication And Standard Care	
Sabina Isabel Lähteenmäki 2021	n=45	Patients who underwent lung biopsies and other minor thoracic operations	EG	1. Inspiratory Muscle Training 2.Walk Minimum 3-4 Rounds On POD1 And Atleast 5 Rounds On POD2	1. Portable Volumetric Spirometry Device. 2. Patient-Reported Daily Walking Distances
			CG	1. Conventional Respiratory Physiotherapy (PEP Group, A Basic Pressure Of 10 Cmh2o Was Used). 2.Walk Minimum 3-4 Rounds On POD1 And Atleast 5 Rounds On POD2	
Jui-Fang Liu 2020	n=54	Lung cancer patients undergoing video-assisted thoracoscopic surgery	EG	1. Inspiratory Muscle Training 2. Aerobic Exercise 3. A Walking Exercise	1. Flow-Directed Incentive Spirometer For Lung Expansion Volume. 2. 6-Min Walk Test For Exercise Capacity.
			CG	Standard Care	
Filipa Kendall 2020	n=63	Lung cancer patients undergoing pulmonary resection by posterolateral thoracotomy	EG	IMT Group Receive IMT EMT Group Received EMT Combt Group Both IMT And EMT CG Recieve Usual Care -Home-Based Respiratory	1. Pulmonary And Respiratory Muscles Function Tests Through Body Plethysmography. 2. Six Minutes' Walk Distance Test (6-MWD).
			CG	Usual Care : Encompassing Pulmonary Expansion Exercises, Bronchial Clearance And General Exercises	
Sabina Lähteenmäki 2020	n=42	Patients undergoing major pulmonary resection surgery	EG	1. IMT Physiotherapy With Threshold IMT Device 2.Walk Minimum 3-4 Rounds On POD1 And Atleast 5 Rounds On POD2	1. Portable Volumetric Spirometry Device. 2. Patient-Reported Daily Walking Distances
			CG	1. Conventional Respiratory Physiotherapy 2.Walk Minimum 3-4 Rounds On POD1 And Atleast 5 Rounds On POD2	
Monique 2019	n=37	Patients undergoing lung cancer resection by muscle-sparing lateral thoracotomy or videothoracoscopy	EG	Combination Of Continuous Aerobic Training And IEMT	1. Exercise Capacity, Measured By CPET As VO2peak.
			CG	Standard Medical Treatment And Periodic Monitoring	
Harun Taşkin 2018	n=40	Patients undergone pulmonary resection	EG	RMT In Addition To Chest Physiotherapy,	1. Maximal Inspiratory Pressure And Maximal Expiratory Pressure Using A Portable Spirometry 2. Exercise Capacity Was Measured Using The 6-Min Walk Test (6MWT).
			CG	Only Chest Physiotherapy	

Abbreviation:
CG: control group , IG: intervention group, IMT: inspiratory muscle training, MVPA : moderate to vigrous physical activity, POD: post-operative day, PEP: positive expiratory pressure, ComT: combine therapy, EMT: expiratory muscle training, MIP: maximal inspiratory pressure, PE max: maximal expiratory pressure, CPET: cardiopulmonary exercise testing, IEMT: inspiratory and expiratory muscle training, RMT : respiratory muscle training. FVC: forced vital capacity, FEV1: forced expiratory volume in 1 second.

group, receiving general exercise instruc-tions, showed less engagement and improvement. Similarly, Kuo *et al.*,[18] reported dramatic improvements in exercise capacity, FEV1, and FVC after a 0–2 week home-based rehabilitation program involving breathing techniques, aerobic exercises, and threshold load training.

Other studies, such as Lähteenmäki *et al.*,[19] RCT, found that combining continuous aerobic training with IMT significantly increased VO_2 peak and respiratory pressures (PImax and PEmax), though no other outcomes showed substantial changes. Kendall *et al.*,[14] study revealed that IMT combined with expiratory muscle training (EMT) and traditional physiotherapy improved inspiratory muscle strength and physical activity, especially in inpatient post-pulmonary resection cases, excluding pneumonectomy cases.

Liu *et al.*,[16] observed enhanced respiratory muscle strength and aerobic capacity in patients undergoing IMT and aerobic exercise routines, with sustained improvements in the 6-minute walk test at 12 weeks post-intervention. Finally, high-intensity IMT showed significant increases in VO2 peak and respiratory pressures, as confirmed by Lähteenmäki *et al.*,[10] and Taşkin *et al.*,[15], reinforcing the efficacy of IMT in improving respiratory health and exercise tolerance. As evi-denced by the various interventions used in the study, IMT is flexible and feasible in various therapeutic settings. These interventions include home-based pro-grams, specialty interventions for particular surgical groups, and combination rehabilitation techniques. The ideal length and timing of IMT interventions and the standardization of IMT processes and long-term outcomes require more study.

Conclusively, the outcomes derived from the thorough examination of the research included in the systematic review reinforce the general agreement that IMT is a successful therapeutic intervention that improves lung functions and exercise capacity, especially when compared to traditional therapies.

One of the strengths of this review is its focus on randomized controlled trials (RCTs) conducted between 2018 and 2023, utilizing valid and reliable instruments to measure outcomes. Further high-quality studies are needed to determine the optimal dosage of inspiratory muscle training to achieve the best outcomes for these patients.

CONCLUSION

In conclusion, the results obtained from the comprehensive analysis of the studies included in the systematic review uphold the widespread consensus that, particularly in comparison to conventional treatments, Inspiratory Muscle Training (IMT) is an efficient therapeutic intervention that enhances lung functions and exercise capacity.

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Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

SS & AS: Data acquisition, data analysis, critical review, approval of the final version to be published.

DZ & SA: Study design, data interpretation, drafting the manuscript, critical review, approval of the final version to be published.

HA & MHR: Conception, data acquisition, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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