LITERATURE REVIEW

The Effects of Inspiratory Muscle Training in Lung Cancer Patients: A Scoping Review

Yolanda Kadir[1], **Rahmaningsih Mara Sabirin**[2], **Ammar Abdurrahman Hasyim**[3], **Roihan Mohamad Iqbal**[4], **Siswanto Siswanto**[2,4*]

[1]Emergency Department, Charitas Hospital, Palembang, Indonesia.
[2]Department of Physiology, Faculty of Medicine, Public Health, and Nursing, Universitas Gadjah Mada, Yogyakarta, Indonesia.
[3]Laboratory of Vaccinology and Applied Immunology, Kanazawa University School of Pharmacy, Ishikawa, Japan.
[4]Division of Pulmonology and Respiratory Medicine, Department of Internal Medicine, Universitas Gadjah Mada Academic Hospital, Yogyakarta, Indonesia.

ARTICLE INFO

Article history:
Received 23 July 2024
Received in revised form
12 December 2024
Accepted 13 December 2024
Available online 30 January 2025

Keywords:
Cancer,
Dyspnea,
Inspiratory muscle training,
Lung cancers.

Cite this as:
Kadir Y, Sabirin RM, Hasyim AA, *et al.* The Effects of Inspiratory Muscle Training in Lung Cancer Patients: A Scoping Review. *J Respi* 2025; 11: 76-83.

ABSTRACT

Introduction: Lung cancer is the leading cause of cancer worldwide, with a high mortality rate. Chronic dyspnea promotes a pathologic cycle of decreased activity, which has been shown to limit exercise tolerance and deteriorate quality of life. Inspiratory muscle training (IMT) is a resistance-based exercise regimen that aims to improve the strength and endurance of the inspiratory muscles, thereby reducing respiratory symptoms. This study aims to comprehensively review the possible beneficial effects of inspiratory muscle training (IMT) on various aspects in lung cancer patients.
Methods: The PubMed, Embase, and Cochrane databases were searched from inception to May 20th, 2024. All clinical trials examining the impact of inspiratory muscle training on lung cancer patients, utilizing either quantitative or qualitative approaches, were included. The data extracted were then descriptively presented, focusing on the main themes to provide a comprehensive review of the literature.
Results: Our search identified 9 unique studies comprising eight randomized-controlled trials and one retrospective cohort study, with a total of 460 lung cancer patients. IMT regimen was proven to reduce sedentary behaviour, along with significant improvement of physical activity and health-related quality of life (HRQL). Furthermore, IMT program reduced dyspnea, with improvement of maximum inspiratory pressure (PImax) and 6-minute walking test (6MWT). It also provided the additional benefits of shorter length of stay postoperatively, and reduced patient's distress with regard to dyspnea.
Conclusion: IMT provides several benefits, including improvements in dyspnea indexes, exercise tolerance, and overall HRQL. Further studies are required to determine the optimal IMT regimen for this special population.

INTRODUCTION

Worldwide, lung cancer continues to be the leading cause of cancer-related deaths.[1] The mortality rate from lung cancer is similar across regions, with 43% of deaths in more developed countries and 57% in less developed countries.[2] In Indonesia, lung cancer accounts for 12.6% of all cancer deaths, making it the top cause of cancer-related mortality. Lung cancer accounted for 8.6% of all cancer cases in 2018, trailing only breast, cervical, and colorectal cancer. The annual incidence is projected to nearly double from 30,023 in 2018 to 54,983 by 2040.[3] Survival rates for lung cancer largely depend on the disease stage and treatment approach. Even with progress in understanding the genetic development of lung cancer, enhanced diagnostic precision, and improved multimodal treatments, the prognosis has not markedly improved, with the 5-year survival rate remaining stagnant at 15% for more than three decades.[4,5]

The most frequently encountered symptoms of lung cancer include shortness of breath (dyspnea), cough, hemoptysis, chest pain, and weight loss.[6] Literature suggests that approximately 75% of patients suffer from dyspnea, and around 90% experience it in the month leading up to their death. Dyspnea is a subjective and multifaceted experience of breathing discomfort. The understanding of "dyspnea" has evolved

*Corresponding author: sis12@ugm.ac.id

Jurnal Respirasi, p-ISSN: 2407-0831; e-ISSN: 2621-8372.
Accredited No. 79/E/KPT/2023; Available at https://e-journal.unair.ac.id/JR. DOI: 10.20473/jr.v11-I.1.2025.76-83

significantly, leading to the professional consensus on the term "chronic breathlessness syndrome," which refers to persistent breathlessness despite optimal treatment of the underlying cause, resulting in disability.[7] This persistent dyspnea, combined with fatigue, establishes a harmful cycle of decreased activity, which is expected to reduce exercise tolerance and negatively affect quality of life (QoL).[8]

Since the 1980s, non-pharmacological methods like inspiratory muscle training (IMT) have been used to manage breathing problems. IMT is a resistance-based exercise program aimed at improving the strength and endurance of the inspiratory muscles. This enhancement helps alleviate respiratory symptoms, boost exercise capacity, and improve health-related quality of life. By fortifying the inspiratory muscles, IMT decreases the effort needed for breathing, thereby reducing dyspnea.[9–11] IMT is often performed with a threshold device that enables airflow during inspiration only after attaining a particular inspiratory pressure, which is adjusted via spring tension that corresponds with a patient's maximal inspiratory pressure. The training load is progressively increased over several initial breaths until the full load has been obtained in the subsequent breaths. This resistance is intended to mimic the length-tension balance of the inspiratory muscles, resulting in a consistent level of training across all lung volumes.[12,13]

In the realm of pulmonary rehabilitation, IMT has gained considerable attention for its advantages, such as higher maximum inspiratory pressure, better sense of wellness, and augmented medical status in patients with advanced cardiac conditions, pulmonary disorders, and exercise-induced breathlessness.[13] Additionally, research has shown that IMT can induce structural alterations in inspiratory muscle fibres.[14] Improvement of inspiratory muscle endurance and strength with IMT technique might potentially help to ameliorate dyspnea, consequently boosting activity levels and enhancing the quality of life for patients with respiratory conditions, including those with lung cancer.[11] Our study aims to comprehensively review the potential benefits of inspiratory muscle training across different aspects in patients with lung cancer. To the best extent of our understanding, this represents the most recent scoping review dedicated to this topic.

METHODS

Scoping reviews are intended to summarise existing research on a particular subject or issue of study. Before conducting the literature scan and data collection, the review methodology was created by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR). The approach included five major steps: defining the research question (in this case, investigating scientific evidence related to the implementation of inspiratory muscle training in lung cancer patients), searching for suitable studies, acquiring studies, retrieving and categorising information, and then demonstrating the findings.[15,16]

Search Strategy

The topic question and search approach were developed using the PCC framework (P: Population, C: Concept, and C: Context. The PubMed, Embase, and Cochrane databases were examined independently from inception to May 20th, 2024, by two reviewers (YK, RMS). The terms "Lung Cancer," "Inspiratory Muscle Training," and "Respiratory Muscle Training" and their corresponding keywords were utilised. To ensure consistency and minimise bias, these terms and keywords were employed both individually and in combination, respecting the specific database requirements. Searches employed terms combined with "AND" and "OR" connectors and were not restricted by a specific time frame. Manual searches of the references from included studies were also performed to find additional related research.

Eligibility Criteria

Study inclusion and exclusion criteria were established before commencing the searches. All clinical trials investigating the effects of inspiratory muscle training on lung cancer patients, using either quantitative or qualitative methods, were included. Articles exploring inspiratory muscle training in conditions other than lung cancer were excluded, as were non-English articles and publications over ten years ago. The headings and abstracts of the acknowledged papers were arranged, and duplicates were removed. Two reviewers (YK and RMS) independently evaluated the research titles and abstracts to obtain studies of interest. Any issues about inclusion or exclusion were handled by consulting with the third author (AAH).

Data Extraction

To finalise the review sample, both reviewers thoroughly evaluated the papers listed according to their eligibility requirements. The reviewers extracted and qualitatively presented information such as authorship, publication year, study methods (including study design, participants, and intervention), main results, and conclusions from the articles. Data were then descriptively analysed, focusing on the main themes to provide a comprehensive review of the literature.

RESULTS

Following searches of various databases, 98 research papers were discovered. Forty-seven identical articles were eliminated, resulting in 51 distinct works. Both reviewers separately reviewed the titles and abstracts of these 51 publications, and 36 articles were excluded because they did not fit the inclusion criteria. The remaining 15 articles were then sought for retrieval. However, two were unable to be obtained. The entire texts of the remaining 13 publications were then examined to establish their significance to the study's aims. Following this full-text review, five articles were removed because they did not address inspiratory muscle training in lung cancer patients. The final sample of this scoping research consisted of eight studies (Figure 1).

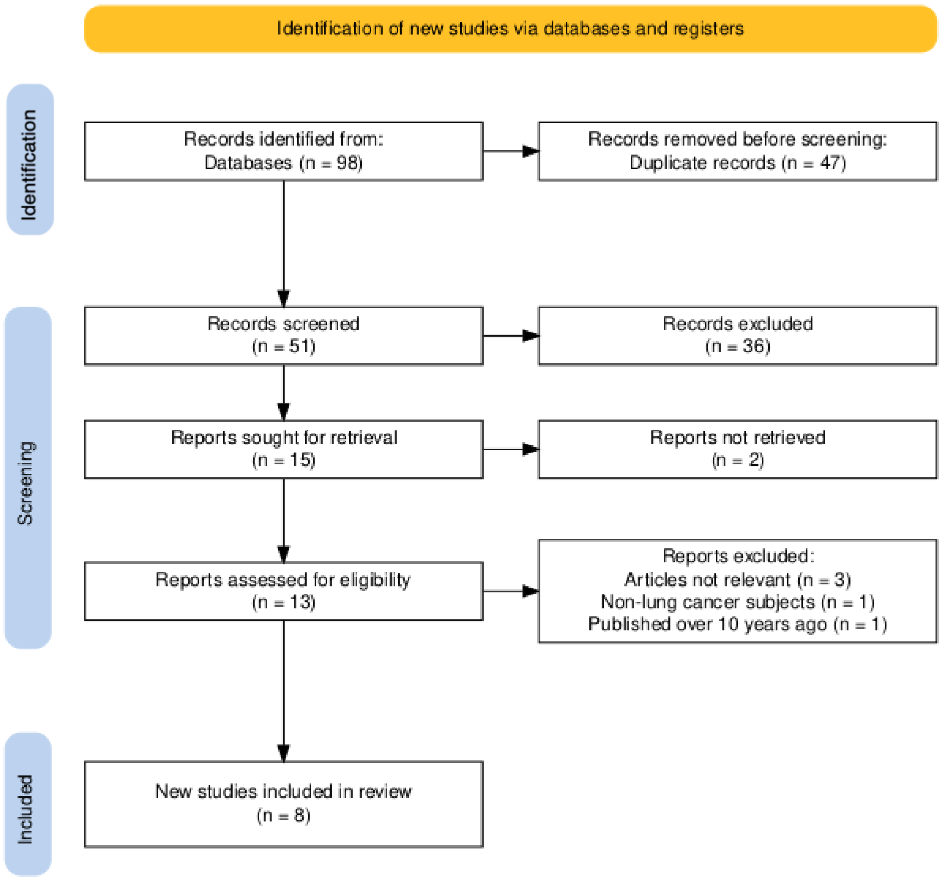

Figure 1. PRISMA flow diagram of resource screening and selection procedure

Table 1 depicts the studies' major overview, which includes authorship, publication year, study methodology, results, and conclusion.

Table 1. Summary of the studies assessed in the scoping review

No.	Author (year)	Study Design	Study Participants	Study Intervention	Results	Conclusion
1.	Ha et al. (2023)[9]	Pilot randomized trial	28 lung cancer patients	12-week telemedicine-based IMT and walking vs. general exercise	Significant improvement in HRQL (SES: -1.03 to -1.30); increased moderate-vigorous intensity physical activity (SES: 1.08); and reduced sedentary behaviour (SES: 0.94).	Telemedicine-based IMT combined with walking was practical, suitable, and secure among patients who had undergone curative therapy, with the potential of interrupting the "dyspnea-inactivity" cycle.
2.	Sakai et al. (2023)[8]	Retrospective cohort	71 lung cancer patients	2-week IMT and exercise therapy vs. exercise therapy only	Significant changes in PImax, with values increasing from 33.2 ± 7.2 cmH2O at baseline to 40.3 ± 8.4 cmH2O at week 1, and further to 42.2 ± 8.4 cmH2O at week 2 ($p < 0.01$). Dyspnea at rest decreased notably, with value from 2.3 ± 0.9 mBS at baseline to 1.4 ± 0.9 mBS at week 1, and to 1.3 ± 1.0 mBS at week 2 ($p < 0.01$). Similarly, dyspnea at exertion was significantly reduced, from 3.8 ± 0.8 mBS at baseline to 2.9 ± 1.0 mBS at week 1, and further to 2.6 ± 0.9 mBS at week 2 ($p < 0.01$).	IMT is effective and has a considerable tenacity rate in those who experienced breathlessness and could not conduct intense physical treatment.
3.	Liu et al. (2021)[17]	Randomized controlled trial	63 lung cancer patients undergoing VATS	6-week IMT and aerobic exercise vs. standard perioperative pulmonary rehabilitation program	Significant improvement in PImax at week 6 (difference: 22.7 ± 2.1 cmH2O, p = 0.018), PEmax at week 2 (difference: 20 ± 3.9 cmH2O, p = 0.015) and week 12 (difference: 22.5 ± 15.1, p = 0.012); significant improvement of lung expansion volume at week 2 (difference: 377 ± 191, p = 0.02) and week 12 (difference: 685 ± 291, $p < 0.001$); improvement of 6MWT at week 2 (difference: 80 ± 4m, p = 0.002), week 6 (difference: 59 ± 10m, p = 0.007) and week 12 (difference: 42 ± 7m, p = 0.036).	The combined use of IMT and aerobic exercise for 6 weeks enhanced the strength of respiratory muscles and exercise endurance starting at two weeks after VATS.
4.	Messagi-Sartor et al. (2019)[18]	Randomized controlled trial	37 NSCLC patients after tumor resection	8-week aerobic exercise and IEMT vs. standard physical activity	Substantial improvement in VO2peak (2.13 mL/Kg/min), PImax (18.96 cm H2O), and PEmax (18.58 cmH2O).	Eight-week fitness regimen involving aerobic activity along with IMT enhanced exercise tolerance and breathing muscle endurance following lung resection.
5.	Brocki et al. (2018)[19]	Randomized controlled trial	68 lung cancer patients undergoing lung resection	2-week postoperative IMT vs. standard physiotherapy	Less sedentary activity 2 weeks after surgery (sedentary 6%, light activity 56%, moderate activity 38%) as opposed to control group (sedentary 22%, light activity 66%, moderate activity 12%; p =0.006).	In high-risk individuals, IMT tends to avert a reduction in physical activity.
6.	Lai et al. (2017)[20]	Randomized controlled trial	60 lung cancer patients undergoing lobectomy	1-week preoperative IMT and aerobic endurance training vs. standard pulmonary rehabilitation	Significant differences were observed in the following measures: 6MWD (difference: 19.2 m, p = 0.029), peak expiratory flow (PEF) (difference: 18.0 L/min, $p < 0.001$), postoperative LoS (3.5 days, p = 0.010), and total hospital stay (3,7 days, p = 0.012).	Intensive lung rehabilitation program (IMT plus endurance exercise) preoperatively could be an effective rehabilitation approach for elderly patients planning for surgery, with beneficial physical and psychological consequences.
7.	Brocki et al. (2016)[21]	Randomized controlled trial	68 lung cancer patients undergoing lung resection	Two-weeks of IMT postoperatively vs. regular physical therapy	Significant improvement in SpO2 levels (Day 3 postoperative: 93.8 ± 3.4; Day 4 postoperative: 93.5 ± 3.5, p = 0.02).	Compared to regular physical therapy alone, two weeks of IMT improved oxygenation in susceptible patients recovering from surgery.
8.	Molassiotis et al. (2015)[11]	Feasibility randomized trial	46 lung cancer patients	12-week IMT sessions vs. standard care	Statistical differences were observed in several areas: difficulties with dyspnea (p = 0.03), ability to manage dyspnea (p = 0.01), contentment from dyspnea control (p = 0.001), exhaustion (p = 0.005), mental performance (p = 0.011), proficiency in managing dyspnea (p = 0.015), and depression (p = 0.028).	IMT is practical and beneficial in individuals with lung cancer.

6MWD: 6-minute walking distance; 6MWT: 6-minute walking test; HRQL: health-related quality of life; IEMT: inspiratory-expiratory muscle training; IMT: inspiratory muscle training; LoS: length of stay; mBS: modified Borg scale; NSCLC: non-small cell lung cancer; PEF: peak expiratory flow; PEmax: maximum expiratory pressure; PImax: maximum inspiratory pressure; SES: standardized sife effect; SpO_2: oxygen saturation, VATS: video-assisted thoracoscopic surgery; VO2 peak: peak oxygen uptake

Of the eight articles included in the analysis, seven were a randomised controlled trial, and one was a retrospective cohort study. This scoping review comprised 441 lung cancer patients as the study cohort. The latest randomised trial by Ha et al.[9] noted that a 12-week inspiratory muscle training provided a significant enhancement of health-related quality of life (HRQL), accompanied by improvement of moderate to vigorous intensity activity levels and reduced sedentary habits. The authors stated that IMT is a practical, suitable, and secure method to disrupt the "dyspnea-inactivity" spiral in lung cancer patients. This result was in line with a previous study by Brocki et al.[19], which demonstrated a reduction of sedentary activity two weeks postoperatively in lung cancer patients undergoing lung resection.

Three studies by Sakai et al.[8], Liu et al.[17], and Messagi-Sartor et al.[18] found a significant improvement in maximum inspiratory pressure (PImax) with a 2-week, 6-week, and 8-week IMT regimen, respectively. Moreover, using a modified Borg scale as the measuring instrument, Sakai et al. demonstrated a significant reduction of dyspnea at rest and dyspnea at exertion. They found that IMT is particularly useful for lung cancer patients who cannot tolerate vigorous physical rehabilitation.[8] Liu et al.[17] further demonstrated an improvement in maximum expiratory pressure (PEmax), lung expansion capacity, and 6-minute walking test (6MWT) as early as the second-week post-VATS. The same result was also described by Lai et al.[20], which found a significantly longer 6-minute walking distance (6MWD) in patients undergoing lobectomy. This positive result was accompanied by huge beneficial effects of reduced postoperative and total hospital stay in these patients.

DISCUSSION

In this scoping review, we found that inspiratory muscle training offers several benefits for lung cancer patients, primarily by alleviating dyspnea symptoms associated with the disease. These findings are pivotal for efforts aimed at reducing breathlessness and enhancing health-associated quality of life in this population. Dyspnea is a critical patient-centred symptom that significantly affects HRQL in those with lung cancer. A high burden of dyspnea can diminish functional exercise capacity and worsen survival rates. Dyspnea intensifies following lung cancer surgery due to a 10-15% decrease in lung function. Over half of those with lung cancer who have survived develop clinically significant dyspnea.[22,23]

Lung cancer survivors often experience worsening dyspnea after curative therapy, which can continue for a considerable time, irrespective of the treatment approach. This condition can arise due to excised or injured lung tissue, harmed or detached nerve filaments, and heightened stimulation of peripheral receptors. Changes in the wall of the thoracic cage, breathing muscles, and respiratory tract can lead to neuromechanical dissociation and increased central 'corollary discharge.[24,25] Patients found the effort required to breathe to be particularly distressing, and this was accompanied by other symptoms such as fatigue, anxiety, loss of appetite, and a decline in the overall sense of well-being and quality of life.[7]

Inspiratory muscle training was previously granted as a promising therapy for people with impaired respiratory muscles. A study of the effects of IMT on inspiratory muscle durability, exercise tolerance, dyspnea, and quality of life in adults with COPD found that IMT regimen significantly enhanced outcomes in inspiratory muscle strength (PImax), endurance, physical activity capability, peak activity rate, and dyspnea.[26] A separate study discovered that a minimal-intensity workout regimen ameliorated pulmonary function, especially vital capacity, in stable COPD patients with PImax levels below 60 cm H2O. IMT has also been shown to drastically enhance PImax, dyspnea, Borg scale ratings, respiratory muscle endurance, incremental load pressure, exercise capacity, and health-associated quality of life in COPD patients.[27]

Continuous pulmonary inflammation caused by several cytokines in COPD promotes a protumor microenvironment, which contributes to lung cancer. Reduced mucociliary clearance may also allow carcinogens to linger in the lungs for an extended amount of time. Furthermore, the COPD lung microbiome differs from that of healthy people, potentially promoting inflammatory responses that contribute to lung cancer pathogenesis.[28,29] As COPD patients are more inclined to develop lung cancer, it is possible that IMT could benefit individuals with lung cancer. Several researchers have indicated that it is uncertain how the progression of COPD affects lung cancer vulnerability, the possibility that both diseases are driven by similar primary factors, or if it is a mix of these factors. Furthermore, the majority of individuals with lung cancer additionally suffer from COPD, as the two conditions are primarily attributable to cigarette use. As a result, a multitude of the manifestations of lung cancer parallel those of COPD.[30,31]

Individuals with COPD and lung cancer exhibit elevated airflow restriction, air accumulation, and lung hyperventilation, putting their respiratory muscles under constant strain. Ventilation becomes shallower and faster, causing symptoms including shortness of breath and decreased exercise capacity. As a result, patients may limit their everyday activities, which can exacerbate their dyspnea and lower their exercise tolerance as well as their quality of life.[11] Improving inspiratory muscle function can assist in preserving the balance between the inspiratory muscles' ability to facilitate breathing and the inspiratory burdens imposed on them, potentially reducing these symptoms.[32]

Breathing muscle performance has successfully been enhanced within the first few days following surgery with preoperative IMT at 30-60% PImax for at least two weeks before the procedure, eliminating the likelihood of postoperative pulmonary issues by fifty per cent.[33] Following pulmonary dissection, the dynamic efficacy of the breathing muscles, particularly the diaphragm, might be hindered due to pleural adhesions as well as temporary chest wall deformation. Similarly, the removal of lung sections might impede ventilatory performance postoperatively, in particular among high-risk patients.[34] The premise behind IMT in this situation is that conditioning with greater amounts of inspiratory resistance may aid in postoperative lung expansion, preserve the integrity of the distal airways, and consequently strengthen diaphragm movement. This could lead to stronger expiratory efforts for secretion clearance, contributing to a quicker restoration of lung function.[21]

IMT seems to be a safe procedure that might induce only short-term adverse effects in a study by Souza et al.[35], thirteen per cent of participants in the intervention group reported respiratory distress during the sessions. However, this adverse effect ceased during the training protocol. Nausea after training sessions was also reported, although this adverse effect ceased after the first month of training protocol. They explained that since all volunteers had a low initial PImax, respiratory distress during the sessions was caused by the higher effort to open the inspiratory valve of the training device. Nausea following training may be due to the use of the mouthpiece, which generates a mouth-breathing pattern correlated to hyperventilation during IMT. Other reported side effects of IMT include paradoxical breathing, desaturation, hemodynamic instability, and supraventricular tachycardia.[36]

It is important to acknowledge the limitations of this scoping review. The topic is still nascent in this field of research, as just eight studies were identified in the three sources reviewed. Among these papers, several limitations were noted, including small sample sizes and inadequate evaluation of other parameters (such as cancer stage, treatment regimen, and comorbidities) that could impact study outcomes. Additionally, the search was restricted to English-language publications, potentially omitting relevant studies and introducing bias into the findings. Regardless of its restrictions, this scoping study provides a solid framework for further research. We highlight the need for more robust studies to provide accordant scientific evidence and potentially establish standardised recommendations regarding the use of IMT for individuals with lung cancer.

SUMMARY

Lung cancer is among the most prevalent type of cancer globally, with a high fatality rate. Chronic dyspnoea in lung cancer patients reduces exercise tolerance and overall quality of life. Inspiratory muscle training, a resistance exercise regimen, has been found to increase inspiratory muscle strength as well as endurance. IMT provides several benefits, including improvements in dyspnea indexes, tolerance for physical activity, and overall health-associated quality of life. Additional research is needed to identify the most effective IMT regimen for this specific population.

Acknowledgments
None declared.

Conflict of Interest
The authors declared there is no conflict of interest.

Funding
None declared.

Authors' Contributions
Conceptualizing, designing: YK, SS. Collecting data, and interpreting results: YK, RMS, AAH. Preparing manuscript and revising: YK, RMS, AAH, RMI, SS. All authors contributed and approved the final version of the manuscript.

REFERENCES

1. Barta JA, Powell CA, Wisnivesky JP. Global Epidemiology of Lung Cancer. Ann Glob Health. 2019;85(1):8. [PubMed]
2. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, et al. Global Cancer Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185 Countries. CA: A Cancer Journal for Clinicians. 2021;71(3):209–49. [PubMed]
3. Andarini S, Syahruddin E, Aditya N, Zaini J, Kurniawan FD, Ermayanti S, et al. Indonesian Society of Respirology (ISR) Consensus Statement on Lung Cancer Screening and Early Detection in Indonesia. Jurnal Respirologi Indonesia. 2023 Apr 19;43(2):144–50. [Journal]
4. Vicidomini G. Current Challenges and Future Advances in Lung Cancer: Genetics, Instrumental Diagnosis and Treatment. Cancers (Basel). 2023 Jul 21;15(14):3710. [PubMed]

5. Ji X, Chen J, Ye J, Xu S, Lin B, Hou K. Epidemiological Analysis of Global and Regional Lung Cancer Mortality: Based on 30-Year Data Analysis of Global Burden Disease Database. Healthcare (Basel). 2023 Nov 7;11(22):2920. [PubMed]
6. Siddiqui F, Vaqar S, Siddiqui AH. Lung Cancer. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 [cited 2024 May 16]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK482357/ [PubMed]
7. Damani A, Ghoshal A, Salins N, Muckaden M, Deodhar J. High Prevalence of Dyspnea in Lung Cancer: An Observational Study. Indian J Palliat Care. 2019;25(3):403–6. [PubMed]
8. Sakai Y, Yamaga T, Yamamoto S, Matsumori K, Ichiyama T, Hanaoka M, et al. Effects and Usefulness of Inspiratory Muscle Training Load in Patients with Advanced Lung Cancer with Dyspnea. J Clin Med. 2023 May 10;12(10):3396. [PubMed]
9. Ha DM, Comer A, Dollar B, Bedoy R, Ford M, Gozansky WS, et al. Telemedicine-based inspiratory muscle training and walking promotion with lung cancer survivors following curative intent therapy: a parallel-group pilot randomized trial. Support Care Cancer. 2023 Sep 1;31(9):546. [PubMed]
10. Hoffman M, Augusto VM, Eduardo DS, Silveira BMF, Lemos MD, Parreira VF. Inspiratory muscle training reduces dyspnea during activities of daily living and improves inspiratory muscle function and quality of life in patients with advanced lung disease. Physiother Theory Pract. 2021 Aug;37(8):895–905. [PubMed]
11. Molassiotis A, Charalambous A, Taylor P, Stamataki Z, Summers Y. The effect of resistance inspiratory muscle training in the management of breathlessness in patients with thoracic malignancies: a feasibility randomised trial. Support Care Cancer. 2015 Jun;23(6):1637–45. [PubMed]
12. Fernández-Lázaro D, Gallego-Gallego D, Corchete LA, Fernández Zoppino D, González-Bernal JJ, García Gómez B, et al. Inspiratory Muscle Training Program Using the PowerBreath®: Does It Have Ergogenic Potential for Respiratory and/or Athletic Performance? A Systematic Review with Meta-Analysis. Int J Environ Res Public Health. 2021 Jun 22;18(13):6703. [PubMed]
13. Vázquez-Gandullo E, Hidalgo-Molina A, Montoro-Ballesteros F, Morales-González M, Muñoz-Ramírez I, Arnedillo-Muñoz A. Inspiratory Muscle Training in Patients with Chronic Obstructive Pulmonary Disease (COPD) as Part of a Respiratory Rehabilitation Program Implementation of Mechanical Devices: A Systematic Review. Int J Environ Res Public Health. 2022 May 3;19(9):5564. [PubMed]
14. Kaeotawee P, Udomittipong K, Nimmannit A, Tovichien P, Palamit A, Charoensitisup P, et al. Effect of Threshold Inspiratory Muscle Training on Functional Fitness and Respiratory Muscle Strength Compared to Incentive Spirometry in Children and Adolescents With Obesity: A Randomized Controlled Trial. Front Pediatr. 2022 Jul 7;10:942076. [PubMed]
15. Mak S, Thomas A. An Introduction to Scoping Reviews. J Grad Med Educ. 2022 Oct;14(5):561–4. [PubMed]
16. Gottlieb M, Haas MRC, Daniel M, Chan TM. The scoping review: A flexible, inclusive, and iterative approach to knowledge synthesis. AEM Educ Train. 2021 Jul 1;5(3):e10609. [PubMed]
17. Liu JF, Kuo NY, Fang TP, Chen JO, Lu HI, Lin HL. A six-week inspiratory muscle training and aerobic exercise improves respiratory muscle strength and exercise capacity in lung cancer patients after video-assisted thoracoscopic surgery: A randomized controlled trial. Clin Rehabil. 2021 Jun;35(6):840–50. [PubMed]
18. Messaggi-Sartor M, Marco E, Martínez-Téllez E, Rodriguez-Fuster A, Palomares C, Chiarella S, et al. Combined aerobic exercise and high-intensity respiratory muscle training in patients surgically treated for non-small cell lung cancer: a pilot randomized clinical trial. Eur J Phys Rehabil Med. 2019 Feb;55(1):113–22. [PubMed]
19. Brocki BC, Andreasen JJ, Westerdahl E. Inspiratory Muscle Training in High-Risk Patients Following Lung Resection May Prevent a Postoperative Decline in Physical Activity Level. Integr Cancer Ther. 2018 Dec;17(4):1095–102. [PubMed]
20. Lai Y, Huang J, Yang M, Su J, Liu J, Che G. Seven-day intensive preoperative rehabilitation for elderly patients with lung cancer: a randomized controlled trial. Journal of Surgical Research. 2017 Mar;209:30–6. [PubMed]
21. Brocki BC, Andreasen JJ, Langer D, Souza DSR, 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 May;49(5):1483–91. [PubMed]
22. Ha D, Ries AL. Characterization of Dyspnea in Veteran Lung Cancer Survivors Following Curative-Intent Therapy. J Cardiopulm Rehabil Prev. 2020 Mar;40(2):120–7. [PubMed]
23. Vainshelboim B, Sardesai SD, Bhammar D. Potential Therapeutic Role of Respiratory Muscle Training in Dyspnea Management of Cancer Survivors: A Narrative Review. World J Oncol. 2024 Jun;15(3):337–47. [PubMed]
24. Brouns I, Verckist L, Pintelon I, Timmermans JP, Adriaensen D. Pulmonary Sensory Receptors. Adv Anat Embryol Cell Biol. 2021;233:1–65. [PubMed]
25. Ohar JA, Mahler DA, Davis GN, Lombardi DA, Moran EJ, Crater GD. Clinical Burden of Chronic Obstructive Pulmonary Disease in Patients with Suboptimal Peak Inspiratory Flow. Can Respir J. 2024;2024:8034923. [PubMed]
26. Ammous O, Feki W, Lotfi T, Khamis AM, Gosselink R, Rebai A, et al. Inspiratory muscle training, with or without concomitant pulmonary

rehabilitation, for chronic obstructive pulmonary disease (COPD). Cochrane Database Syst Rev. 2023 Jan 6;1(1):CD013778. [PubMed]
27. Iwakura M, Okura K, Kubota M, Sugawara K, Kawagoshi A, Takahashi H, et al. Estimation of minimal clinically important difference for quadriceps and inspiratory muscle strength in older outpatients with chronic obstructive pulmonary disease: a prospective cohort study. Phys Ther Res. 2021;24(1):35–42. [PubMed]
28. Criner GJ, Agusti A, Borghaei H, Friedberg J, Martinez FJ, Miyamoto C, et al. Chronic Obstructive Pulmonary Disease and Lung Cancer: A Review for Clinicians. Chronic Obstr Pulm Dis. 9(3):454–76. [PubMed]
29. Qi C, Sun SW, Xiong XZ. From COPD to Lung Cancer: Mechanisms Linking, Diagnosis, Treatment, and Prognosis. Int J Chron Obstruct Pulmon Dis. 2022 Oct 17;17:2603–21. [PubMed]
30. Fang H, Dong T, Li S, Zhang Y, Han Z, Liu M, et al. A Bibliometric Analysis of Comorbidity of COPD and Lung Cancer: Research Status and Future Directions. Int J Chron Obstruct Pulmon Dis. 2023;18:3049–65. [PubMed]
31. Liu Y, Feng ZW, Liu XM, Duan HY, Lyu ZY, Huang YB, et al. Association of Lung Cancer Risk With the Presence of Both Lung Nodules and Emphysema in a Lung Cancer Screening Trial. World J Oncol. 2024 Apr;15(2):246–56. [PubMed]
32. Figueiredo RIN, Azambuja AM, Cureau FV, Sbruzzi G. Inspiratory Muscle Training in COPD. Respir Care. 2020 Aug;65(8):1189–201. [PubMed]
33. Bingül ES, Şentürk NM, Kaynar AM. Prehabilitation: a narrative review focused on exercise therapy for the prevention of postoperative pulmonary complications following lung resection. Front Med (Lausanne). 2023;10:1196981. [PubMed]
34. Shin S, Kong S, Kang D, Lee G, Cho JH, Shim YM, et al. Longitudinal changes in pulmonary function and patient-reported outcomes after lung cancer surgery. Respiratory Research. 2022 Aug 30;23(1):224. [PubMed]
35. Souza H, Rocha T, Pessoa M, Rattes C, Brandao D, Fregonezi G, et al. Effects of Inspiratory Muscle Training in Elderly Women on Respiratory Muscle Strength, Diaphragm Thickness and Mobility. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences. 2014 Dec 1;69(12):1545–53. [PubMed]
36. Luo Z, Qian H, Zhang X, Wang Y, Wang J, Yu P. Effectiveness and safety of inspiratory muscle training in patients with pulmonary hypertension: A systematic review and meta-analysis. Front Cardiovasc Med. 2022;9:999422. [PubMed]