Majalah Ilmiah Fisioterapi Indonesia
Indonesian Scientific Journal of Physiotherapy

Case Reports
ISSN (Print): 2303-1921
ISSN (Online): 2722-0443
Volume 14, Number 1, Pages 83-90 (2026)
DOI: https://doi.org/10.24843/mifi.000001060

Effect of Inspiratory Muscle Training on Peak Expiratory Flow After Thoracic Surgery: A Case Report

Astrid Risma Priyanka[1], Isnaini Herawati[2]

[1,2]Department of Physiotherapy, Faculty of Health Sciences, Universitas Muhammadiyah Surakarta, Indonesia

Corresponding author:
Name: Isnaini Herawati
E-mail: ih166@ums.ac.id
Phone: +62 881-5672-9074

Received 9 December 2025; Revised 29 December 2025; Accepted 4 January 2026; Published 4 January 2026

Abstract
Background: Post-thoracic surgery patients commonly experience respiratory muscle dysfunction, reduced lung volumes, impaired cough effectiveness, and decreased peak expiratory flow. Inspiratory muscle training using incentive spirometry is widely applied in pulmonary rehabilitation to facilitate postoperative recovery. However, evidence describing its short-term effects on peak expiratory flow with daily monitoring remains limited.
Objective: To evaluate the effect of inspiratory muscle training using incentive spirometry on peak expiratory flow in a post-thoracic surgery patient.
Methods: This case report involved a 40-year-old male patient who underwent thoracic surgery for spontaneous pneumothorax and lung cancer. The patient presented with dyspnea, postoperative pain, and altered breathing patterns. Inspiratory muscle training using incentive spirometry was administered twice daily for 10 consecutive days. Peak expiratory flow was measured before and after the intervention using a peak flow meter. Pain and dyspnea were assessed using the Wong–Baker Faces Pain Rating Scale and the Borg Scale.
Results: Peak expiratory flow increased from 100 L/min to 350 L/min after 10 days of intervention. Pain scores decreased from 5/10 to 2/10, and dyspnea scores improved from 7 (very severe) to 2 (mild). The average daily improvement in peak expiratory flow was 25 L/min.
Conclusion: Inspiratory muscle training using incentive spirometry improved peak expiratory flow and alleviated pain and dyspnea in a post-thoracic surgery patient, supporting its role in early postoperative pulmonary rehabilitation.

Keywords
Inspiratory Muscle Training; Incentive Spirometry; Peak Expiratory Flow; Thoracic Surgery; Pulmonary Rehabilitation

Introduction

Thoracic surgery is a major surgical procedure involving operative intervention within the thoracic cavity to treat conditions affecting the lungs, pleura, mediastinum, chest wall, diaphragm, or major airways. Common indications include lung cancer, esophageal malignancy, spontaneous pneumothorax, and other structural or neoplastic thoracic disorders.[1] Advances in surgical techniques have improved survival outcomes; however, postoperative pulmonary complications remain a substantial clinical challenge and a major contributor to postoperative morbidity and prolonged hospitalization.[2]

Globally, thoracic surgical procedures continue to increase, particularly for lung cancer management. Large national and institutional databases have reported high procedural volumes, with lobectomy being the most frequently performed operation.[3,4] Despite improvements in perioperative care, thoracic surgery is classified as major surgery requiring general anesthesia, which is associated with rapid reductions in functional residual capacity, impaired diaphragmatic function, and altered chest wall mechanics.[5] These physiological changes compromise respiratory muscle performance, reduce lung volumes, and impair effective coughing, thereby increasing the risk of postoperative pulmonary complications.[6]

Postoperative pulmonary complications encompass a wide range of respiratory disorders, including atelectasis, pleural effusion, pneumonia, bronchospasm, pneumothorax, aspiration pneumonitis, acute respiratory distress syndrome, and respiratory failure.[6] The reported incidence ranges from approximately 1% to 30%, depending on patient characteristics, surgical complexity, and perioperative management strategies.[5] Importantly, postoperative pulmonary complications are associated with increased mortality, prolonged hospitalization, higher healthcare costs, and delayed functional recovery.[6]

Physiological mechanisms underlying postoperative pulmonary dysfunction include respiratory muscle inhibition due to pain, reduced thoracic mobility, diaphragmatic dysfunction, impaired mucociliary clearance, and ventilation–perfusion mismatch. Thoracotomy incisions and intercostal muscle trauma further restrict chest wall expansion and alter rib kinematics, leading to shallow breathing patterns and reduced inspiratory capacity.[6]

Physiotherapy plays a critical role in preventing and managing postoperative pulmonary complications through early mobilization, breathing exercises, airway clearance techniques, and respiratory muscle training.[7] Common physiotherapeutic interventions include chest physiotherapy, deep breathing exercises, active cycle of breathing techniques, postural drainage, incentive spirometry, and respiratory muscle training.[8-9] These interventions aim to optimize ventilation, enhance respiratory muscle performance, promote lung expansion, and facilitate secretion clearance during the postoperative period.

Inspiratory muscle training is a specific form of respiratory rehabilitation designed to strengthen the inspiratory muscles by imposing resistance during inhalation.[10] Incentive spirometry is one of the most widely used modalities to facilitate inspiratory muscle training, particularly in postoperative settings.[11,9] This device provides visual feedback that encourages slow, deep inspirations, thereby promoting diaphragmatic activation and lung expansion.[12]

The physiological benefits of incentive spirometry include increased inspiratory capacity, enhanced alveolar ventilation, improved diaphragmatic excursion, and prevention of alveolar collapse.[13] By increasing lung volumes during inspiration, incentive spirometry may indirectly improve expiratory performance, as greater inspiratory volume allows for more forceful expiration. Consequently, respiratory muscle strength and airflow dynamics may be reflected in improvements in peak expiratory flow.[14,15]

Peak expiratory flow represents the maximum airflow achieved during a forceful expiration following maximal inspiration and serves as an objective indicator of airway patency and respiratory muscle performance.[16] Reduced peak expiratory flow values indicate increased airway resistance, weakened respiratory muscles, or suboptimal lung expansion.[17] In postoperative thoracic surgery patients, peak expiratory flow may be particularly affected due to pain-related inhibition, reduced chest wall compliance, and impaired inspiratory effort.[18]

Although several studies have demonstrated improvements in pulmonary function following inspiratory muscle training or incentive spirometry, most investigations have relied on pre- and post-intervention measurements only.[19,15] Evidence describing the daily progression of peak expiratory flow during the early postoperative period remains limited, particularly in thoracic surgery patients. Continuous monitoring may provide deeper insight into respiratory recovery trajectories and responsiveness to inspiratory muscle training.

Therefore, this case report aims to evaluate the effect of inspiratory muscle training using incentive spirometry on peak expiratory flow in a patient following thoracic surgery, with daily assessment over a 10-day intervention period. The findings are expected to support evidence-based physiotherapy practice in early postoperative pulmonary rehabilitation.

Methods

Study Design

This study employed a single-patient pre–post interventional case report design to evaluate the short-term effects of inspiratory muscle training using incentive spirometry on peak expiratory flow following thoracic surgery. This design was selected to allow detailed clinical observation, daily outcome monitoring, and in-depth documentation of the patient's physiological response during the early postoperative period. Case report methodology is appropriate for generating preliminary clinical evidence and describing recovery trajectories when randomized or controlled designs are not feasible.[20]

Participant and Setting

The participant was a 40-year-old male patient admitted to Dr. Ario Wirawan Pulmonary Hospital, Salatiga, Indonesia, following thoracic surgery. The surgical procedure was performed in July 2025 and consisted of a right middle lobe lobectomy and bullae resection due to spontaneous pneumothorax and lung cancer. Postoperatively, the patient was initially treated in the intensive care unit before being transferred to the general ward.

The patient worked as a self-employed individual and had a medical history of chronic obstructive pulmonary disease and hypertension. He was an active smoker with a smoking history of approximately 6–10 cigarettes per day for seven years. The patient reported no known drug or food allergies and had no previous surgical history.

Eligibility Criteria

Inclusion criteria were defined as patients who had undergone thoracic surgery, were clinically stable, able to communicate effectively, capable of understanding verbal instructions, and had received joint postoperative care by a thoracic surgeon and a rehabilitation medicine specialist. Patients were required to have received formal consultation and approval from the rehabilitation medicine specialist prior to physiotherapy intervention. Exclusion criteria included refusal of consent by the patient or legal guardian, presence of neuromuscular disorders affecting respiratory function, cognitive impairment limiting cooperation, or any medical instability contraindicating respiratory physiotherapy.

Clinical Assessment

Baseline assessment was conducted prior to physiotherapy intervention and included subjective and objective examinations. Subjective complaints consisted of dyspnea, postoperative pain accompanied by localized swelling at the surgical site, and altered breathing patterns. Differential diagnoses considered during clinical assessment included atelectasis, pleural effusion, pneumonia, post-thoracotomy pain syndrome, and subcutaneous emphysema as potential postoperative sequelae.

Objective examination revealed positive fremitus and wheezing, with auscultation demonstrating rhonchi. Chest expansion measurements were obtained at three anatomical landmarks: the fourth to fifth intercostal space (70–71 cm), axillary level (64–65 cm), and xiphoid process level (73–74 cm). Surgical incision inspection was also performed to monitor wound status.

Pain intensity was assessed using the Wong–Baker Faces Pain Rating Scale, a validated pain assessment tool frequently used in clinical and critical care settings.[21] The baseline pain score was recorded as 5 out of 10, indicating moderate pain. Dyspnea severity was evaluated using the Borg Rating of Perceived Exertion Scale, which quantifies breathlessness on a scale ranging from 0 (no dyspnea) to 10 (maximal dyspnea).[22] The baseline Borg score was 7, indicating very severe dyspnea.

Outcome Measures

The primary outcome measure was peak expiratory flow, assessed using a peak flow meter. Peak expiratory flow represents the maximum airflow generated during a forceful expiration following maximal inspiration and serves as a simple, objective indicator of airway patency and respiratory muscle performance.[16]

Peak expiratory flow measurement was performed using standardized procedures. The mouthpiece was disinfected with an alcohol swab prior to use, and the device marker was reset to zero. The patient was positioned in an upright sitting or standing posture and instructed to inhale maximally, followed by a rapid and forceful expiration into the device. Three trials were performed, and the highest value was recorded for analysis.[23]

Secondary outcome measures included pain intensity assessed using the Wong–Baker Faces Pain Rating Scale and dyspnea severity measured using the Borg Scale.[21,22] These measures were recorded daily to monitor symptom progression and intervention safety.

Validity and Reliability of Measurement Tools

Peak flow meters are widely used for measuring peak expiratory flow due to their simplicity, low cost, and adequate sensitivity for detecting changes in pulmonary function. Despite their low technological complexity, peak flow meters demonstrate acceptable validity and reliability for assessing airway function and respiratory performance in both clinical and postoperative settings.[18]

The Wong–Baker Faces Pain Rating Scale has demonstrated validity and reliability in assessing pain intensity across various patient populations, including postoperative and critically ill patients.[21] Similarly, the Borg Scale is a validated instrument for assessing perceived dyspnea and exertion during respiratory and physical activity.[22]

Intervention Protocol

The physiotherapy intervention consisted of inspiratory muscle training using an incentive spirometry device. Prior to initiating the intervention, baseline peak expiratory flow was measured each morning to determine pre-intervention values. During incentive spirometry training, the patient was positioned in a relaxed sitting posture, and the device was held upright at eye level to ensure accurate visual feedback. The patient held the spirometer with one hand and sealed the lips tightly around the mouthpiece.[24]

The patient was instructed to perform three normal tidal breaths, followed by a slow and maximal inhalation through the mouthpiece, aiming to elevate the piston indicator as high as possible. The inspiratory breath was held for approximately 3–5 seconds, depending on patient tolerance, before slowly exhaling and removing the mouthpiece. The exercise was discontinued if dizziness or excessive dyspnea occurred.[25]

Inspiratory muscle training was administered twice daily for 10 consecutive days. Morning sessions were supervised by a physiotherapist, while afternoon sessions were performed independently by the patient as a home-based program. Safety monitoring was conducted daily using the Borg Scale and Wong–Baker Faces Pain Rating Scale. In addition to incentive spirometry, the patient received adjunct physiotherapy interventions, including active cycle of breathing techniques and progressive mobilization, adjusted according to daily clinical improvement and tolerance.

Data Analysis

Changes in peak expiratory flow were analyzed by calculating the percentage change between baseline and final values (ΔPEF) and the average daily rate of improvement expressed in liters per minute per day.[16] Due to the single-patient case report design, inferential statistical testing was not performed, and results were presented descriptively.

Results

Participant Flow and Clinical Course

The patient underwent thoracic surgery in early July 2025 and was admitted to the intensive care unit for postoperative monitoring before being transferred to the general ward. Physiotherapy intervention commenced after medical clearance and continued for 10 consecutive days. No adverse events or intervention-related complications were reported throughout the intervention period. The overall clinical course and intervention timeline are summarized in Figure 1**.**

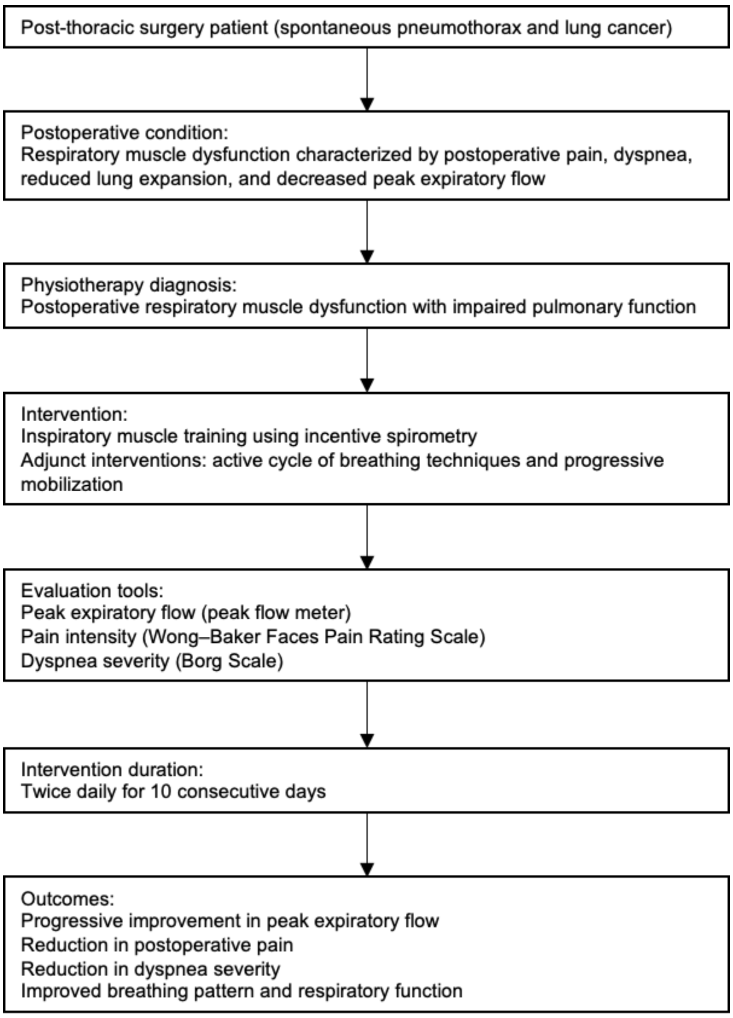


Figure 1. Case flow diagram illustrating patient status, physiotherapy diagnosis, intervention, evaluation tools, and clinical outcomes following thoracic surgery.

Baseline Characteristics

Baseline demographic and clinical characteristics of the patient are presented in Table 1. At baseline, the patient exhibited moderate postoperative pain, severe dyspnea, and markedly reduced peak expiratory flow.

Table 1. Baseline Characteristics of the Patient

Characteristic	Value
Age (years)	40
Sex	Male
Occupation	Self-employed
Primary diagnosis	Post-thoracic surgery due to spontaneous pneumothorax and lung cancer
Surgical procedure	Right middle lobectomy and bullae resection
Comorbidities	Chronic obstructive pulmonary disease, hypertension
Smoking history	Active smoker (6–10 cigarettes/day for 7 years)
Blood pressure	103/77 mmHg
Heart rate	77 beats/min
Respiratory rate	22 breaths/min
Oxygen saturation	95%
Body temperature	36.7 °C
Pain score (Wong–Baker)	5/10
Dyspnea score (Borg)	7
Peak expiratory flow	100 L/min

Changes in Peak Expiratory Flow

Daily measurements demonstrated a progressive increase in peak expiratory flow over the 10-day intervention period. Baseline peak expiratory flow was 100 L/min on day 1 and increased steadily to 350 L/min by day 10. The total percentage improvement (ΔPEF) was 250%, with an average daily increase of approximately 25 L/min. Pre- and post-session peak expiratory flow values for each intervention day are detailed in Table 2.

Table 2. Daily Peak Expiratory Flow Values Before and After Incentive Spirometry

Day	Pre-intervention PEF (L/min)	Post-intervention PEF (L/min)
1	100	200
2	100	200
3	130	210
4	150	200
5	150	220
6	200	250
7	200	250
8	220	300
9	250	300
10	280	350

Pain and Dyspnea Outcomes

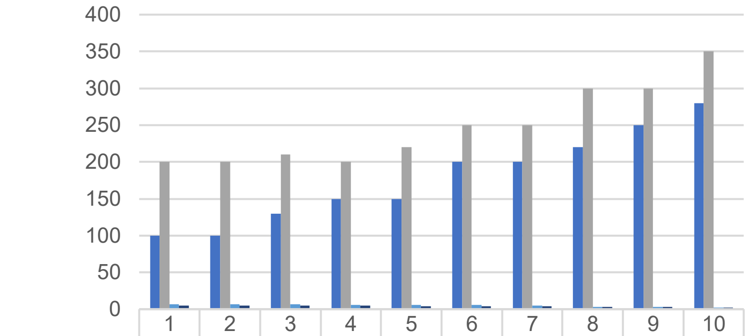
Pain intensity and dyspnea severity showed consistent reductions throughout the intervention period. Wong–Baker pain scores decreased from 5/10 at baseline to 2/10 at day 10. Borg dyspnea scores improved from 7 (very severe) at baseline to 2 (mild) at the end of the intervention. Daily changes in pain and dyspnea are summarized in Table 3.

Table 3. Daily Pain and Dyspnea Scores During the Intervention Period

Day	Pain Score (Wong–Baker)	Dyspnea Score (Borg)
1	5	7
2	5	7
3	5	7
4	5	6
5	4	6
6	4	6
7	4	5
8	3	3
9	3	3
10	2	2

Graphical Representation of Outcomes

The trends in peak expiratory flow, pain scores, and dyspnea scores over the 10-day intervention period are illustrated in Figure 2. The figure demonstrates a gradual increase in peak expiratory flow alongside concurrent reductions in pain and dyspnea.



	1	2	3	4	5	6	7	8	9	10
PEF (Pre)	100	100	130	150	150	200	200	220	250	280
PEF(Post)	200	200	210	200	220	250	250	300	300	350
Borg Scale	7	7	7	6	6	6	5	3	3	2
WBS	5	5	5	5	4	4	4	3	3	2

Figure 2. Daily changes in peak expiratory flow (L/min), Wong–Baker pain scores, and Borg dyspnea scores during the 10-day inspiratory muscle training intervention.

Follow-up

No post-intervention follow-up beyond day 10 was conducted due to time constraints and limited patient accessibility. All outcome data presented reflect measurements obtained during the intervention period only.

Discussion

This case report demonstrated that inspiratory muscle training using incentive spirometry was associated with a progressive improvement in peak expiratory flow, accompanied by reductions in postoperative pain and dyspnea in a patient following thoracic surgery. Over a 10-day intervention period, peak expiratory flow increased substantially, while symptom severity showed consistent daily improvement. These findings highlight the potential role of inspiratory muscle training as an effective component of early postoperative pulmonary rehabilitation.

Post-thoracic surgery patients are particularly vulnerable to postoperative pulmonary dysfunction due to multiple interacting factors, including diaphragmatic inhibition, chest wall rigidity, pain-induced shallow breathing, and impaired cough effectiveness. Thoracic incisions and intercostal muscle trauma disrupt normal thoracic mechanics and reduce inspiratory effort, leading to decreased lung volumes and compromised expiratory airflow.[5,6] In this context, interventions targeting respiratory muscle performance are clinically relevant for restoring pulmonary function and preventing secondary complications.

The observed improvement in peak expiratory flow in this case is consistent with the physiological mechanisms underlying inspiratory muscle training. Incentive spirometry encourages slow, maximal inspirations that promote diaphragmatic activation, increase inspiratory capacity, and enhance alveolar recruitment.[11,9] By improving inspiratory volume and respiratory muscle strength, patients may generate greater intrathoracic pressure during subsequent expiration, resulting in higher peak expiratory flow values.[14,15] This mechanism aligns with previous studies reporting improvements in expiratory flow parameters following respiratory muscle training interventions.[19]

Although peak expiratory flow is often used as a surrogate marker for airway patency, it also reflects the functional capacity of the respiratory muscles. Reduced peak expiratory flow following thoracic surgery may indicate pain-limited effort, weakened inspiratory and expiratory muscles, or increased airway resistance.[16,18] In the present case, baseline peak expiratory flow was markedly reduced, suggesting substantial postoperative respiratory impairment. The gradual daily increase observed during the intervention period suggests a progressive recovery of respiratory muscle performance and ventilatory efficiency.

Importantly, the final peak expiratory flow value reached 350 L/min, representing a clinically meaningful improvement. Although this value remained below the normal reference range for adult males, typically reported as approximately 500–700 L/min, the improvement exceeded the threshold associated with reduced risk of postoperative pulmonary complications. Previous studies have reported that peak expiratory flow values below 300 L/min following lobectomy are associated with a higher incidence of complications such as pneumonia and atelectasis.[16,18] Therefore, surpassing this threshold may confer tangible clinical benefits, even if full normalization is not achieved in the early postoperative period.

The reduction in pain and dyspnea observed in this case likely contributed to the improvement in peak expiratory flow. Postoperative pain is a major limiting factor for effective breathing, as patients tend to avoid deep inspiration and forceful expiration to minimize discomfort.[26] Pain-related inhibition of respiratory muscle activity can substantially reduce expiratory airflow generation.[27] The concurrent reduction in Wong–Baker pain scores suggests improved tolerance to respiratory effort, which may have facilitated more effective inspiratory muscle training and enhanced expiratory performance.

Similarly, the improvement in dyspnea severity, as measured by the Borg Scale, reflects enhanced ventilatory efficiency and reduced respiratory effort. Inspiratory muscle training has been shown to reduce the sensation of breathlessness by improving respiratory muscle strength and endurance, thereby lowering the relative load placed on the respiratory system during breathing.[28,29] The parallel improvements in peak expiratory flow, pain, and dyspnea observed in this case support the interrelated nature of these clinical outcomes.

The findings of this case report are consistent with previous studies examining the effects of incentive spirometry and inspiratory muscle training in postoperative populations. Comparative studies have reported clinically significant improvements in peak expiratory flow and other pulmonary function parameters following the use of incentive spirometry, even when differences between device types were not statistically significant.[30] Additionally, studies involving post-tracheostomy and post-abdominal surgery patients have demonstrated similar improvements in peak expiratory flow and lung volumes following incentive spirometry interventions.[31,32] These findings suggest that incentive spirometry may provide broad benefits across different surgical populations.

However, the present case report adds novel insight by documenting daily changes in peak expiratory flow rather than relying solely on pre- and post-intervention measurements. Daily monitoring allowed for a more detailed understanding of the recovery trajectory and highlighted the gradual, cumulative nature of respiratory improvement. This approach may be particularly useful in clinical practice, as it enables early identification of suboptimal progress and facilitates timely modification of rehabilitation strategies.

Despite these encouraging findings, several limitations must be acknowledged. First, the single-patient case report design inherently limits generalizability. Without a control condition or comparison group, it is not possible to definitively attribute the observed improvements solely to inspiratory muscle training, as spontaneous postoperative recovery and concurrent physiotherapy interventions may have contributed to the outcomes. Second, the short follow-up duration precludes assessment of long-term sustainability of the observed improvements. Third, the presence of comorbid chronic obstructive pulmonary disease and a history of smoking may have influenced baseline pulmonary function and recovery dynamics, potentially limiting extrapolation to other patient populations.

Additionally, the patient received adjunct physiotherapy interventions, including active cycle of breathing techniques and progressive mobilization, which may have acted synergistically with inspiratory muscle training. While this reflects real-world clinical practice, it complicates attribution of effects to a single intervention. Future studies employing randomized controlled designs, larger sample sizes, and standardized intervention protocols are needed to isolate the specific contribution of inspiratory muscle training to postoperative pulmonary recovery.

From a clinical perspective, this case report supports the feasibility, safety, and potential effectiveness of inspiratory muscle training using incentive spirometry in the early postoperative period following thoracic surgery. The intervention was well tolerated, easily implemented, and required minimal equipment. Moreover, the use of simple monitoring tools such as peak expiratory flow meters, pain scales, and dyspnea scales provides clinicians with objective and subjective measures to guide rehabilitation progression.

Future research should explore the optimal timing, dosage, and duration of inspiratory muscle training, as well as its long-term effects on pulmonary function, functional capacity, and postoperative complication rates. Incorporating daily monitoring of respiratory outcomes into study designs may further enhance understanding of recovery patterns and inform individualized rehabilitation strategies.

Conclusion

This case report demonstrated that inspiratory muscle training using incentive spirometry was associated with a meaningful improvement in peak expiratory flow, accompanied by reductions in postoperative pain and dyspnea in a patient following thoracic surgery. Over a 10-day intervention period, peak expiratory flow increased progressively, indicating improved respiratory muscle performance and ventilatory efficiency during early postoperative recovery.

The observed improvements suggest that inspiratory muscle training may facilitate pulmonary function recovery by enhancing inspiratory capacity, supporting more effective expiratory airflow generation, and reducing respiratory effort. Concurrent reductions in pain and dyspnea likely contributed to improved breathing mechanics and greater tolerance for respiratory training. Although the final peak expiratory flow value did not reach normative reference ranges for healthy adult males, surpassing clinically relevant thresholds may still provide important protective benefits against postoperative pulmonary complications.

From a clinical perspective, incentive spirometry represents a simple, low-cost, and easily implemented intervention that can be incorporated into early postoperative pulmonary rehabilitation programs. The use of peak expiratory flow monitoring, alongside pain and dyspnea assessment, offers clinicians practical and objective tools to track patient progress and guide individualized rehabilitation strategies.

Despite these positive findings, the single-patient case report design limits generalizability and precludes causal inference. The absence of a control condition, short follow-up duration, and presence of comorbidities further constrain interpretation. Future research employing randomized controlled trials, larger sample sizes, longer intervention periods, and longitudinal follow-up is warranted to confirm these findings and to establish optimal training protocols. Nevertheless, this case report contributes preliminary clinical evidence supporting the role of inspiratory muscle training using incentive spirometry in early postoperative care following thoracic surgery.

Author Contribution

Astrid Risma Priyanka: Conceptualization, Methodology, Data curation, Formal analysis, Writing—original draft.
Isnaini Herawati: Conceptualization, Writing—review & editing, Supervision.

Acknowledgments

The authors express their sincere gratitude to the Department of Physiotherapy, Faculty of Health Sciences, Universitas Muhammadiyah Surakarta, and Dr. Ario Wirawan Pulmonary Hospital, Salatiga, for their support and cooperation during this study. The authors also thank the patient for participating and providing consent for publication.

Conflict of Interest Statement

The authors declare no conflict of interest.

Funding Sources

This study received no external funding.

Ethics Statement

This study was approved by the Ethics Committee of Dr. Ario Wirawan Pulmonary Hospital, Salatiga, Indonesia (Ethical Approval No. DP.04.03/D.XL.9.7/026/2025). Written informed consent was obtained from the patient after a comprehensive explanation of the study procedures, objectives, potential benefits, and risks. Patient confidentiality and privacy were strictly maintained, and written consent for publication was obtained.

References

1. Anshori IF, Riana D. Prediction of life expectancy in lung cancer patients after thoracic surgery using boosted neural network and SMOTE. J Infomedia. 2021;6(1):9.
2. Janne PA, Baik C, Su WC, Johnson ML, Hayashi H, Nishio M, et al. Efficacy and safety of patritumab deruxtecan in EGFR inhibitor–resistant EGFR-mutated non–small cell lung cancer. Cancer Discov. 2022;12(1):74–89.

3. Yamamoto T, Takahashi A, Yoshizumi T, Ishihara S, Inomata M, Imoto S, et al. 2023 national clinical database annual report by the Japan Surgical Society. Surg Today. 2025;55(3):295–334.
4. Wang Y, Gu Z, Yao F, Mao T, Wang R, Sun Y, et al. Annual report of thoracic surgery services at the Shanghai Chest Hospital in 2020. Shanghai Chest. 2022;6(1):[pages not available].
5. Taylor A, DeBoard Z, Gauvin JM. Prevention of postoperative pulmonary complications. Surg Clin North Am. 2015;95(2):237–254.
6. Miskovic A, Lumb AB. Postoperative pulmonary complications. Br J Anaesth. 2017;118(3):317–334.
7. Bertolaccini L, Mohamed S, Uslenghi C, Chiari M, Girelli L, Lo Iacono G, et al. A practical assessment of postoperative management in lung cancer surgery. J Pers Med. 2023;13(2):[pages not available].
8. Boden I, Skinner EH, Browning L, Reeve J, Anderson L, Hill C, et al. Preoperative physiotherapy for prevention of respiratory complications after upper abdominal surgery: a pragmatic multicentre randomized controlled trial. BMJ. 2018;360:j5916.
9. Eltorai AEM, Szabo AL, Antoci V, Ventetuolo CE, Elias JA, Daniels AH, et al. Clinical effectiveness of incentive spirometry for prevention of postoperative pulmonary complications. Respir Care. 2018;63(3):347–352.
10. Xu W, Li R, Guan L, Wang K, Hu Y, Xu L, et al. Combination of inspiratory and expiratory muscle training. Respir Res. 2018;19:203.
11. Restrepo RD, Wettstein R, Wittnebel L, Tracy M. Incentive spirometry: 2011. Respir Care. 2011;56(10):1600–1604.
12. Franklin E, Anjum F. Incentive spirometer and inspiratory muscle training. StatPearls. 2023;[pages not available].
13. Othman EM, Abaas SA, Hassan HH. Resisted breathing exercise versus incentive spirometer training on vital capacity after radical cystectomy: a pilot randomized controlled trial. Bull Fac Phys Ther. 2016;21(2):61–67.
14. Patil R, NS, Veena V. Peak flow meter and digital spirometer: a comparative study of peak expiratory flow rate values. Natl J Physiol Pharm Pharmacol. 2020;10(4):1–6.
15. Kumar AS, Alaparthi GK, Augustine AJ, Pazpazhyaottayil ZC, Ramakrishna A, Krishnakumar SK. Comparison of flow and volume incentive spirometry on pulmonary function after open abdominal surgery. J Clin Diagn Res. 2016;10(1):KC01–KC06.
16. DeVrieze BW, Goldin J, Giwa AO. Peak flow rate measurement. StatPearls. 2023;[pages not available].
17. Scheeren CFC, Goncalves JJS. Comparative evaluation of ventilatory function using pre- and postoperative peak expiratory flow in elective upper abdominal surgery. Rev Col Bras Cir. 2016;43(3):165–170.
18. Lai Y, Wang X, Li P, Li J, Zhou K, Che G. Preoperative peak expiratory flow for predicting postoperative pulmonary complications after lung cancer lobectomy. J Thorac Dis. 2018;10(7):4293–4301.
19. Handayani A, WSP. Effect of inspiratory muscle training on respiratory status in chronic obstructive pulmonary disease. Al-Asalmiya Nurs J. 2021;10(2):71–77.
20. Mannan MAU, Anjum KK, Zahid F. Comparison of incentive spirometry and peak expiratory flow meter to evaluate cardiopulmonary parameters after valvular surgery. Med J South Punjab. 2024;5(2):1–7.
21. Arsyawina, Mardiyono, Sarkum. Comparison of CPOT and Wong–Baker Faces Pain Rating Scale in mechanically ventilated patients. J Ris Kesehat. 2019;3(1):1–5.
22. Hamidah NA, Presditia IM, Nugraha DA. Effectiveness of nebulizer, breathing control, and effective coughing on dyspnea and functional activity. J Ilm Kesehat. 2024;16(2):287–294.
23. Butsainah D, Multazam A, Lubis ZI. Association between incense exposure duration and peak expiratory flow in Jembrana Bali community. J Upin. 2025;5(1):55–62.
24. Kadu D. Incentive spirometer and respiratory muscle training devices: what physiotherapists need to know. J Pulm Respir Med. 2023;13(1):62.
25. Sutjana IDP, Imron MA, Muliarta IM, Adiputra IN, Dewi NNA. Addition of incentive spirometry to deep breathing exercise on pulmonary function after cardiac surgery. Sport Fit J. 2020;8(1):62–71.
26. Zhou T, Sun C. Effect of pulmonary rehabilitation with physical manipulation after thoracoscopic lobectomy. Thorac Cancer. 2022;13(3):308–315.
27. Oslock WM, Xie R, Donahue J, Wei B. Lung resection and new postoperative home oxygen requirement: a systematic review. J Thorac Dis. 2024;16(12):8796–8806.
28. Vorona S, Sabatini U, Al-Maqbali S, Bertoni M, Dres M, Bissett B, et al. Inspiratory muscle rehabilitation in critically ill adults: a systematic review and meta-analysis. Ann Am Thorac Soc. 2018;15(6):735–744.
29. Pereira MC, Dacha S, Testelmans D, Gosselink R, Langer D. Effects of inspiratory muscle training in unilateral diaphragm dysfunction. Breathe. 2019;15(2):e90–e96.
30. Sathe AM, Bhandare SA. Comparison of flow and volume incentive spirometry on peak expiratory flow and single breath count after sternotomy. Int J Health Sci Res. 2022;12(8):167–180.
31. Ganesh AS, Abathsagayam K, Ravisankar NP. Impact of volume-oriented incentive spirometry on lung volume and peak expiratory flow in tracheostomy patients. Cureus. 2024;16(3):e56820.
32. Nandi B, Mishra S, Yeole U, Gawali P, Adkitte R. Effectiveness of incentive spirometry in improving peak expiratory flow after abdominal surgery. Physiother Thesis J Med Thesis. 2015;3(1):15–18.