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Incentive Spirometer and Inspiratory Muscle Training

Emily Franklin; Fatima Anjum.

Author Information and Affiliations

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Continuing Education Activity

Postoperatively, pulmonary complications require extraordinary attention from the medical community, as they are a direct cause of morbidity and mortality. The incentive spirometer can be easily used in pulmonary rehabilitation as a tool in inspiratory muscle training to reduce or prevent postoperative pulmonary complications and exercise the lungs. This activity reviews the use of the incentive spirometer in inspiratory muscle training and highlights the role of the interprofessional team in evaluating, treating, and managing the care of patients who meet the criteria to receive pulmonary rehabilitation.

Objectives:

- Describe the proper use of an incentive spirometer.
- Identify indications for incentive spirometry and inspiratory muscle training.
- Review anatomy and physiology of lungs and diaphragm during inspiration.
- Outline the clinical significance inspiratory muscle training has on pulmonary complication prevention by an interprofessional team.

Access free multiple choice questions on this topic.

Introduction

An incentive spirometer is a device that measures the volume of the air inhaled into the lungs during inspiration. When breathing in through an incentive spirometer, a piston rises inside the device and measures the volume of the inspired air. The incentive spirometry device is widely used in physical, speech, and respiratory therapy as it encourages the patient to perform a slow and deep inspiration through visual feedback.[1] Breathing in slowly is important with spirometer use as it allows the lungs to stretch and opens the airways, which is intended to imitate the deep breathing seen in yawning or sighing.[2]

The incentive spirometer uses visual feedback to assess a patient's inspiratory effort by measuring the inhalation volume. The incentive spirometer can be used in rehabilitation as a favorable tool, as it is inexpensive and easy to manage with no known side effects. It is simple to train and does not require assistance once a patient has learned how to use it properly. Furthermore, the visual feedback encourages patient compliance.[1]

The use of the incentive spirometer in inspiratory muscle training has been shown to maintain or increase inhaled lung volume, prevent lung infection after surgery, and improve sputum expectoration. Although research on the effectiveness of incentive spirometry for chronic conditions is mixed, inspiratory muscle training is a vital factor in reducing or preventing

postoperative pulmonary complications. Using an incentive spirometer following surgery can help preserve the lungs' integrity and keep the lungs clear. Deep breathing supports the movement of secretions and assists in opening lung spaces that may have become collapsed. Inspiratory muscle training stretches and exercises the lungs, keeping them engaged, especially while recovering from surgery.[2]

Anatomy and Physiology

The respiratory system constitutes an efficient delivery system of inspired oxygenated air to all portions of the lungs within an enclosed space. The lungs provide a large surface area for gas exchange with the cardiovascular system. The lungs can provide adequate gas exchange at rest or while withstanding mechanical stresses such as when exercising. Sophisticated regulatory mechanisms at every level of the process work together to ensure that the constantly changing capacities of perfusion, ventilation, diffusion and chemical binding to hemoglobin are optimal for every aspect of demand encountered by the human body.[3]

The right ventricle pumps deoxygenated blood to the lungs through the pulmonary valve via the main pulmonary artery. The short but wide artery then splits into the right and left pulmonary arteries at the level of the T4 vertebrae. The right pulmonary artery supplies deoxygenated blood to the right lung, while the left pulmonary artery supplies deoxygenated blood to the left lung. The arteries continue to subdivide and eventually become capillaries. While in the capillaries, the blood gives off carbon dioxide through the capillary wall into the alveoli of the lungs. Simultaneously, the blood takes up oxygen from the air in the alveoli, and oxygenated blood is returned to the left atrium via pulmonary veins. It is a very efficient system, making the pulmonary circulation ideal for the highest level of gas exchange.[4]

During inspiration, the diaphragm and external intercostal muscle contractions cause lung volume expansion. Following inspiration, the inspiratory muscles relax, and laryngeal muscles constrict to slow the lung compression. During active expiration, internal intercostal muscles and abdominal muscles contract depending upon metabolic needs.[5]

Indications

There are many indications for inspiratory muscle training, including but not limited to the following.

1. **Any general surgery requiring hospital admission beyond one day**[6]: Incentive spirometry use by itself is not appropriate in the preoperative and postoperative setting to prevent postoperative pulmonary complications. Instead, incentive spirometry can be used with other aspects of pulmonary rehabilitation, including deep breathing techniques, directed coughing, adequate pain control, and early mobilization to prevent postoperative pulmonary complications.[7] The incentive spirometer regimen includes ten workouts per day, used correctly (i.e., inspire up to 500ml ten times per workout). Other postoperative interventions to prevent lung complications include but are not limited to oral care, elevating the head of the bed at least 30 degrees, dangling legs the day of surgery if indicated, transferring multiple times per day when cleared by the surgeon, ambulation, and sitting up for meals.[6]
2. **Prolonged bed rest**: Prolonged immobilization affects almost every organ system in the body. Respiratory complications include decreased ventilation, atelectasis, and pneumonia. Atelectasis is the collapse of the entire lung or part of the lung. It occurs when the alveoli

within the lungs become deflated or possibly filled with fluid. Atelectasis is one of the most common respiratory complications after surgery.[8]

3. **Patients with neuromuscular disease or spinal cord injury**: Cervical and upper thoracic spinal cord injury cause impairments in respiratory muscle performance, leading to pulmonary dysfunction and making deep breathing difficult for affected individuals. Patients with tetraplegia have a more compromised pulmonary function as compared with patients with paraplegia. Respiratory muscle training should be a focus in all spinal cord injury rehabilitation programs, especially for patients with tetraplegia, as well as those with chronic spinal cord injury.[9]

4. **Children with cerebral palsy**: Incentive spirometry has been shown to enhance pulmonary function and breath control for speech production in children with cerebral palsy.[10]

5. **Rib fractures**: Several complications can follow rib fracture, including hemothorax, pneumothorax, lung contusion, atelectasis, respiratory failure, flail chest, and even death. Patients suffering from rib fractures frequently complain of chest pain, which can be caused by obstruction of the lower airway or damaged lung hygiene. This can lead to atelectasis and hypoventilation. Atelectasis is the most common complication following rib fractures. Incentive spirometry has been shown to decrease pulmonary complications in patients with rib fractures and improve pulmonary function.[11]

6. **Chronic obstructive pulmonary disease (COPD)**: COPD is a common, preventable lung disease characterized by progressive difficulty with breathing, often with systemic manifestations, in response to tobacco smoke and/or other harmful exposures to the lungs.[12] The reported benefits of pulmonary rehabilitation on COPD exacerbations have been mixed, but the balance of evidence supports its use. Pulmonary rehabilitation may reduce future COPD exacerbations by targeting risk factors that may cause readmission to the hospital, such as physical inactivity, reduced activity tolerance, impaired physical function, desensitization to shortness of breath, anxiety, and depression.[13] Short-term inspiratory muscle training and incentive spirometer use have beneficial effects on exercise capacity and exertional dyspnea in patients with COPD.[14] Pulmonary rehabilitation of a patient with COPD needs to be used in conjunction with lifestyle changes, smoking cessation, and physical exercise to better manage the disease; incentive spirometry cannot be used alone.[15]

7. **Video-assisted thoracoscopic surgery (VATS) for lung cancer**: The use of incentive spirometry and inspiratory muscle training for patients with lung cancer that choose to undergo surgical resection via VATS has been shown to assist with lowering hospitalization costs and decreasing the prevalence of pneumonia incidents.[16]

8. **Sickle Cell Disease**: Acute chest syndrome is a frequent cause of acute lung dysfunction in children with sickle cell disease. Management of acute chest syndrome includes immediate diagnosis, intravenous fluids, incentive spirometry, analgesics, supplemental oxygen or respiratory support, antibiotics, and transfusion therapy.[17]

9. **Ankylosing Spondylitis:** Incentive spirometry may improve pulmonary function and arterial blood gases in patients with ankylosing spondylitis.[1]

10. **Parkinson's disease**: Respiratory dysfunction is not a well-known feature of Parkinson's disease. Inspiratory muscle weakness may be present early in the course of the disease. In

the more advanced stages, limited chest mobility, poor posture, and lung expansion contribute to less effective coughing. This could lead to the occurrence of aspiration pneumonia, which is among the highest risk factors for mortality for patients in the advanced stages of Parkinson's disease. Inspiratory muscle training can be helpful when people with Parkinson's disease are experiencing respiratory dysfunction.[18]

11. **Mild to moderate asthma:** Breathing exercises may positively affect the quality of life, hyperventilation symptoms, and lung function in adults with mild to moderate asthma.[19]
12. **Cystic Fibrosis:** The incentive spirometer may aid airway clearance and improve lung function in patients with cystic fibrosis.[20]
13. **COVID-19:** Pulmonary rehabilitation, including inspiratory muscle training, is indicated in patients with mild to severe COVID-19 symptoms, including pneumonia and difficulties with secretion clearance. Training of inspiratory musculature also has significant benefits in patients who have been treated with mechanical ventilation. In patients with a dry, nonproductive cough, fever, and/or demonstrate no changes in thorax radiography, breathing techniques are not indicated.[21]
14. **Idiopathic pulmonary fibrosis**: Pulmonary rehabilitation has been shown to alleviate respiratory symptoms and improve exercise tolerance. The improvements may be related to the chest expansion during deep-breathing exercises and the stretching of the thoracic muscles resulting in a more efficient breathing pattern, improved respiratory muscle strength, and pulmonary compliance. Most studies on pulmonary rehabilitation in idiopathic pulmonary fibrosis combine aerobic activity (walking and/or cycling) with resistance and flexibility exercises for peripheral skeletal muscles. Pulmonary rehabilitation should be considered at any stage of the idiopathic pulmonary fibrosis disease process and in patients awaiting lung transplantation.[22]
15. **Interstitial Lung Disease**: Interstitial lung disease is one of the most serious pulmonary complications of connective tissue diseases. Non-pharmacological interventions include exercises such as walking, strength training, inspiratory muscle training, and breathing exercises.[23]
16. **Multiple Sclerosis:** Resistive inspiratory muscle training may effectively improve maximal inspiratory pressure in people with mild to moderate multiple sclerosis. [24] Further research and studies are needed.

Contraindications

Certain precautions need to be taken when using an incentive spirometer. Although there is no absolute contraindication for spirometry, the following conditions are considered a need for caution when performing inspiratory muscle training: the presence of a respiratory tract infection, hemoptysis of unknown origin, pneumothorax, uncontrolled hypertension, aneurysm, recent thoracic, abdominal, or eye surgery, nausea, vomiting or pain, and confusion or dementia. [25]

Patients with bullous emphysema should be cautious of using an incentive spirometer with high intensity. There has been a report of a patient with emphysema that was thought to sustain a partial lung collapse following aggressive use of an incentive spirometer. The development of the pneumothorax may have been related to the patient's repeated forceful inspirations under resistance in the setting of emphysema and lung hyperinflation. Inspiratory breathing under

resistance can cause large swings in intrathoracic pressure, resulting in increased stress on the lung tissue.[26]

Equipment

The incentive spirometer is a mechanical hand-held breathing device in which the patient is instructed to take slow deep breaths through the device's mouthpiece. The device gives the patient visual feedback on the volume of the inhalation. Incentive spirometers are available either by measuring the volume of inspiration (volume-oriented devices) or measuring the flow rate (flow-oriented devices). A standard flow-oriented incentive spirometer consists of three chambers in a row. The patient inhales through a mouthpiece connected to the unit with the three chambers. Each chamber contains a ball that has printed on the outside of the chamber the least amount of flow needed to raise the ball. With an airflow rate of 600 to 1200 milliliters (mL) per second, the deep breath lifts the balls. When all three balls reach the top of the unit, the patient has reached a flow speed of 1200 mL/second. The colored balls indirectly give the patient a visual indication of the inhaled volume. The visual feedback works to improve compliance in performing the slow, sustained deep inspiration.

The most common volume-oriented incentive spirometer is a mechanical hand-held device that uses a one-way valve to block exhalation into the device. It consists of a corrugated hose and a mouthpiece that connects the patient to a plastic chamber. Next to the central chamber of the spirometer is a slider. The medical provider can use this slider to set a target breath volume. The target breath volume can be based on the patient's age, height, health, and condition. When the patient breathes in through the corrugated hose, the piston in the chamber rises, which indicates the volume of displacement via an indicator on the device. There is a smaller chamber on the spirometer that measures the speed of the breath. The ball in this chamber will go to the top if the patient breathing in too quickly, and will go to the bottom if breathing too slowly. Many spirometers have a line on this chamber to indicate the optimal speed.

Once the patient has achieved maximal inspiratory volume to the best of their ability, the patient is requested to hold the piston in the same position for 5 to 10 seconds. After completing the inhalation and maintaining that inhalation for the appropriate amount of time, the patient is instructed to remove the mouthpiece, allowing gravity to return the piston to its original starting point.

Studies have proposed that there are significant differences between the volume and flow-oriented incentive spirometer. Volume-oriented devices cause less effort with breathing and more exercise of the diaphragm, whereas flow-oriented devices cause increased muscular activity of the upper chest. Volume-oriented incentive spirometry has shown to be more effective in improving pulmonary function, functional capacity, and functional difficulty questionnaire when compared to flow-oriented incentive spirometry and diaphragmatic breathing exercises.[27]

Personnel

There are no legal regulations on who can perform incentive spirometry.[28]

Technique

Sitting or standing in a comfortable position with proper posture and supporting the incentive spirometer in the correct, upright position, the patient is encouraged to take slow, deliberate inhales through the mouthpiece. The patient is encouraged to achieve a certain volume which can

vary based on the patient's height and age. The patient receives visible feedback from the piston rising to the preset marker that the clinician has set. The patient is instructed to hold his breath for at least 2 or 3 seconds at a minimum at full inspiration. Expiration is performed slowly and calmly with lips no longer sealed around the mouthpiece. After a series of 10 inhalations, coughing should be prompted to further clear the lungs of phlegm. It is advised to repeat incentive spirometer use for at least ten deep breaths every hour while awake.[2]

The breathing pattern when using an incentive spirometer is significant and should be communicated to the patient. The patient should be shown how to expand the lower chest at maximal inspiration rather than use the accessory muscles of inhalation. The patient should focus on expanding the lower ribcage instead of expanding only the upper chest.[2] Studies have shown that slow-maintained inspirations used in volumetric incentive spirometry effectively promote lung expansion rather than fast inspirations.[29]

Complications

Inspiratory muscle training exercises have few complications. Exercises can be modified through duration and intensity depending on the frailty of the patient. The focus should be on the quality of the slow deep breath with the goal of achieving at least 500 ccs of inspiratory volume for each breath. The patient should be educated on the after-effects that can be caused by deep breathing, such as coughing.[2]

Clinical Significance

Typical postoperative pulmonary complications include atelectasis, hypoxemia, pneumonia, respiratory dysfunction, hypoventilation, and pleural effusion. The physiological changes that may occur can be related to the anesthesia, the type of incision, and the type of surgical technique.

A common postoperative complication is a lack of lung expansion, resulting from a shift in normal breathing to an increase in shallow breathing without periodic sighs or yawns. The change in breathing pattern can be caused by laying in a prolonged recumbent position, decreased mucociliary clearance, and/or impaired cough performance secondary to pain, increasing the risks associated with decreased pulmonary secretions.

Pulmonary rehabilitation plays a major role in the prevention and management of postoperative pulmonary complications. This includes deep breathing exercises, inspiratory muscle training, mobilization, postural drainage, and percussion. Mechanical breathing devices such as the incentive spirometer have been introduced into clinical practice as a tool to assist with lung expansion.[30]

Postoperative pulmonary complications are too common and cause increased mortality and longer hospital stays, and increased hospital readmissions. Smoking and respiratory diseases, including obstructive sleep apnea, asthma, and chronic obstructive pulmonary disease, are correlated with developing postoperative pulmonary complications. Other risk factors for pulmonary complications include recent respiratory infection or low pre-operative oxygen saturation levels. Evidence has shown that smoking cessation prior to surgery may reduce pulmonary complications. Pre-operative inspiratory muscle training programs that include the use of an incentive spirometer may reduce postoperative pulmonary complications. Pre-operative exercise programs are recommended for patients undergoing surgery or patients with low levels of cardiorespiratory fitness.[31]

Enhancing Healthcare Team Outcomes

Postoperative pulmonary complications require extraordinary attention from the entire medical community, as they are a direct cause of morbidity and mortality. The incentive spirometer can be easily used in pulmonary rehabilitation as a tool in inspiratory muscle training to reduce or prevent postoperative pulmonary complications and exercise the lungs. The role of the interprofessional team is critical in evaluating, treating, and managing the care of patients who are indicated to receive pulmonary rehabilitation.

Any medical professional providing bedside care to a patient at risk for pulmonary complications should be educated in inspiratory muscle training and verify that the patient is proficient in using an incentive spirometer. To derive good outcomes, the goals and objective of using the incentive spirometer must be defined for the patient's compliance to be at the optimal level. An incentive spirometer regimen should include ten workouts per day, used correctly (i.e., inspire up to 500 ml ten times per workout).

Other postoperative interventions to prevent lung complications include but are not limited to oral care, elevating the head of the bed at least 30 degrees, dangling legs the day of surgery if indicated, transferring multiple times per day when cleared by the surgeon, ambulation, and sitting up for meals.[6] Because incentive spirometry does not require special training, it is every medical professional's responsibility to address this with the patient.

To improve outcomes in the postoperative setting, the role of the nurse and therapist is critical. The nurses will assist the team by monitoring the patient to ensure pain is adequately controlled and communicate with the clinician as needed if any common postoperative complications such as atelectasis are suspected. The therapist can assist by preventing prolonged immobilization and encouraging transfers and mobility training when indicated.[8]

Further emphasizing the need for an interprofessional approach to the prevention of pulmonary complications includes the need for meticulous planning and discussion with other professionals involved in managing the patient. Quick and efficient patient training on an incentive spirometer may prevent morbidity, prevent future hospitalizations, and improve outcomes.[6] [Level 1]

Review Questions

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References

1. So MW, Heo HM, Koo BS, Kim YG, Lee CK, Yoo B. Efficacy of incentive spirometer exercise on pulmonary functions of patients with ankylosing spondylitis stabilized by tumor necrosis factor inhibitor therapy. J Rheumatol. 2012 Sep;39(9):1854-8. [PubMed: 22859343]
2. Hristara-Papadopoulou A, Tsanakas J, Diomou G, Papadopoulou O. Current devices of respiratory physiotherapy. Hippokratia. 2008;12(4):211-20. [PMC free article: PMC2580042] [PubMed: 19158964]
3. Hsia CC, Hyde DM, Weibel ER. Lung Structure and the Intrinsic Challenges of Gas Exchange. Compr Physiol. 2016 Mar 15;6(2):827-95. [PMC free article: PMC5026132] [PubMed: 27065169]
4. Tucker WD, Weber C, Burns B. StatPearls [Internet]. StatPearls Publishing; Treasure Island (FL): Jul 25, 2022. Anatomy, Thorax, Heart Pulmonary Arteries. [PubMed: 30521233]

5. Romano V, Reddington AL, Cazzanelli S, Mazza R, Ma Y, Strydis C, Negrello M, Bosman LWJ, De Zeeuw CI. Functional Convergence of Autonomic and Sensorimotor Processing in the Lateral Cerebellum. Cell Rep. 2020 Jul 07;32(1):107867. [PMC free article: PMC7351113] [PubMed: 32640232]
6. Fuchshuber PR, Greif W, Tidwell CR, Klemm MS, Frydel C, Wali A, Rosas E, Clopp MP. The power of the National Surgical Quality Improvement Program--achieving a zero pneumonia rate in general surgery patients. Perm J. 2012 Winter;16(1):39-45. [PMC free article: PMC3327110] [PubMed: 22529758]
7. Restrepo RD, Wettstein R, Wittnebel L, Tracy M. Incentive spirometry: 2011. Respir Care. 2011 Oct;56(10):1600-4. [PubMed: 22008401]
8. Teasell R, Dittmer DK. Complications of immobilization and bed rest. Part 2: Other complications. Can Fam Physician. 1993 Jun;39:1440-2, 1445-6. [PMC free article: PMC2379609] [PubMed: 8324412]
9. Shin JC, Han EY, Cho KH, Im SH. Improvement in Pulmonary Function with Short-term Rehabilitation Treatment in Spinal Cord Injury Patients. Sci Rep. 2019 Nov 19;9(1):17091. [PMC free article: PMC6863911] [PubMed: 31745108]
10. Choi JY, Rha DW, Park ES. Change in Pulmonary Function after Incentive Spirometer Exercise in Children with Spastic Cerebral Palsy: A Randomized Controlled Study. Yonsei Med J. 2016 May;57(3):769-75. [PMC free article: PMC4800370] [PubMed: 26996580]
11. Sum SK, Peng YC, Yin SY, Huang PF, Wang YC, Chen TP, Tung HH, Yeh CH. Using an incentive spirometer reduces pulmonary complications in patients with traumatic rib fractures: a randomized controlled trial. Trials. 2019 Dec 30;20(1):797. [PMC free article: PMC6937666] [PubMed: 31888765]
12. Gupta D, Agarwal R, Aggarwal AN, Maturu VN, Dhooria S, Prasad KT, Sehgal IS, Yenge LB, Jindal A, Singh N, Ghoshal AG, Khilnani GC, Samaria JK, Gaur SN, Behera D., S. K. Jindal for the COPD Guidelines Working Group. Guidelines for diagnosis and management of chronic obstructive pulmonary disease: Joint ICS/NCCP (I) recommendations. Lung India. 2013 Jul;30(3):228-67. [PMC free article: PMC3775210] [PubMed: 24049265]
13. Halpin DM, Miravitlles M, Metzdorf N, Celli B. Impact and prevention of severe exacerbations of COPD: a review of the evidence. Int J Chron Obstruct Pulmon Dis. 2017;12:2891-2908. [PMC free article: PMC5638577] [PubMed: 29062228]
14. Bavarsad MB, Shariati A, Eidani E, Latifi M. The effect of home-based inspiratory muscle training on exercise capacity, exertional dyspnea and pulmonary function in COPD patients. Iran J Nurs Midwifery Res. 2015 Sep-Oct;20(5):613-8. [PMC free article: PMC4598910] [PubMed: 26457101]
15. Hill K, Vogiatzis I, Burtin C. The importance of components of pulmonary rehabilitation, other than exercise training, in COPD. Eur Respir Rev. 2013 Sep 01;22(129):405-13. [PMC free article: PMC9487370] [PubMed: 23997066]
16. Liu CJ, Tsai WC, Chu CC, Muo CH, Chung WS. Is incentive spirometry beneficial for patients with lung cancer receiving video-assisted thoracic surgery? BMC Pulm Med. 2019 Jul 08;19(1):121. [PMC free article: PMC6615301] [PubMed: 31286923]
17. Jain S, Bakshi N, Krishnamurti L. Acute Chest Syndrome in Children with Sickle Cell Disease. Pediatr Allergy Immunol Pulmonol. 2017 Dec 01;30(4):191-201. [PMC free article: PMC5733742] [PubMed: 29279787]
18. van de Wetering-van Dongen VA, Kalf JG, van der Wees PJ, Bloem BR, Nijkrake MJ. The Effects of Respiratory Training in Parkinson's Disease: A Systematic Review. J Parkinsons Dis. 2020;10(4):1315-1333. [PMC free article: PMC7683068] [PubMed: 32986684]
19.

Santino TA, Chaves GS, Freitas DA, Fregonezi GA, Mendonça KM. Breathing exercises for adults with asthma. Cochrane Database Syst Rev. 2020 Mar 25;3(3):CD001277. [PMC free article: PMC7096190] [PubMed: 32212422]

20. Sokol G, Vilozni D, Hakimi R, Lavie M, Sarouk I, Bat-El Bar, Dagan A, Ofek M, Efrati O. The Short-Term Effect of Breathing Tasks Via an Incentive Spirometer on Lung Function Compared With Autogenic Drainage in Subjects With Cystic Fibrosis. Respir Care. 2015 Dec;60(12):1819-25. [PubMed: 26374905]
21. Bernal-Utrera C, Anarte-Lazo E, Gonzalez-Gerez JJ, De-La-Barrera-Aranda E, Saavedra-Hernandez M, Rodriguez-Blanco C. Could Physical Therapy Interventions Be Adopted in the Management of Critically Ill Patients with COVID-19? A Scoping Review. Int J Environ Res Public Health. 2021 Feb 08;18(4) [PMC free article: PMC7915254] [PubMed: 33567748]
22. Spagnolo P, Tzouvelekis A, Bonella F. The Management of Patients With Idiopathic Pulmonary Fibrosis. Front Med (Lausanne). 2018;5:148. [PMC free article: PMC6036121] [PubMed: 30013972]
23. Vacchi C, Sebastiani M, Cassone G, Cerri S, Della Casa G, Salvarani C, Manfredi A. Therapeutic Options for the Treatment of Interstitial Lung Disease Related to Connective Tissue Diseases. A Narrative Review. J Clin Med. 2020 Feb 03;9(2) [PMC free article: PMC7073957] [PubMed: 32028635]
24. Rietberg MB, Veerbeek JM, Gosselink R, Kwakkel G, van Wegen EE. Respiratory muscle training for multiple sclerosis. Cochrane Database Syst Rev. 2017 Dec 21;12(12):CD009424. [PMC free article: PMC6486138] [PubMed: 29267988]
25. Jat KR. Spirometry in children. Prim Care Respir J. 2013 Jun;22(2):221-9. [PMC free article: PMC6442789] [PubMed: 23732636]
26. Kenny JE, Kuschner WG. Pneumothorax caused by aggressive use of an incentive spirometer in a patient with emphysema. Respir Care. 2013 Jul;58(7):e77-9. [PubMed: 23232741]
27. Amin R, Alaparthi GK, Samuel SR, Bairapareddy KC, Raghavan H, Vaishali K. Effects of three pulmonary ventilation regimes in patients undergoing coronary artery bypass graft surgery: a randomized clinical trial. Sci Rep. 2021 Mar 24;11(1):6730. [PMC free article: PMC7990944] [PubMed: 33762655]
28. Coates AL, Graham BL, McFadden RG, McParland C, Moosa D, Provencher S, Road J., Canadian Thoracic Society. Spirometry in primary care. Can Respir J. 2013 Jan-Feb;20(1):13-21. [PMC free article: PMC3628641] [PubMed: 23457669]
29. Alaparthi GK, Augustine AJ, Anand R, Mahale A. Comparison of Diaphragmatic Breathing Exercise, Volume and Flow Incentive Spirometry, on Diaphragm Excursion and Pulmonary Function in Patients Undergoing Laparoscopic Surgery: A Randomized Controlled Trial. Minim Invasive Surg. 2016;2016:1967532. [PMC free article: PMC4972934] [PubMed: 27525116]
30. Kumar AS, Alaparthi GK, Augustine AJ, Pazhyaottayil ZC, Ramakrishna A, Krishnakumar SK. Comparison of Flow and Volume Incentive Spirometry on Pulmonary Function and Exercise Tolerance in Open Abdominal Surgery: A Randomized Clinical Trial. J Clin Diagn Res. 2016 Jan;10(1):KC01-6. [PMC free article: PMC4740618] [PubMed: 26894090]
31. Lumb AB. Pre-operative respiratory optimisation: an expert review. Anaesthesia. 2019 Jan;74 Suppl 1:43-48. [PubMed: 30604419]

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