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Exploring the Therapeutic Potential of Lung Flute Device in Enhancing Vital Functions in Tuberculosis Patients

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ABSTRACT

Background: Pulmonary Tuberculosis (TB) remains a major global health concern, often leading to compromised pulmonary function even after medical treatment. Techniques to improve lung clearance and oxygenation are essential to enhance recovery. **Objective:** This experimental study explores the therapeutic efficacy of an airway clearance device (Lung Flute) in enhancing pulmonary function in patients diagnosed with Pulmonary TB. **Methods:** A total of 60 participants each diagnosed with pulmonary TB were randomly assigned to use either the Lung Flute device or standard care over a defined intervention period. Pre- and post-intervention values of physiological markers such as heart rate (HR), systolic and diastolic blood pressure (BP), and oxygen saturation (SpO₂) were recorded. Data were analyzed using SPSS, including descriptive statistics, Pearson correlation, and normality testing. **Results:** The device showed improvements in post-intervention HR, BP, and SpO₂. Pearson correlation analyses revealed significant correlations between pre- and post-intervention values across most physiological parameters. **Conclusion:** The Lung Flute devices can be effective adjunct in pulmonary rehabilitation among TB patients. These findings suggest the clinical utility of oscillatory PEP devices in physiotherapy protocols for TB.

INTRODUCTION:

Pulmonary Tuberculosis (TB) remains a leading cause of morbidity and mortality, particularly in low and middle income countries (World Health Organization, 2023). Despite the availability of effective pharmacological treatments, TB often results in long-lasting impairment of pulmonary function due to structural damage, chronic inflammation, and airway obstruction (Gupta et al., 2021).

Physiotherapeutic interventions aimed at improving lung ventilation, secretion clearance and oxygenation have gained increased importance in TB rehabilitation. Among these, Positive Expiratory Pressure (PEP) devices such as the Acapella and Lung Flute are widely used to assist airway clearance and enhance lung function. The Acapella combines resistive and vibratory PEP therapy to mobilize secretions, while the Lung Flute uses sound waves generated by exhalation to

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loosen mucus in the lungs (Volsko, 2013; King et al., 2010).

Several studies have demonstrated the efficacy of PEP devices in conditions such as Chronic Obstructive Pulmonary Disease (COPD), bronchiectasis, and cystic fibrosis, but there is limited evidence regarding their impact on pulmonary TB patients (Ahmed & Vellappally, 2020; Agostini & Knowles, 2007). Given the pathophysiological overlap in airway secretions and pulmonary compromise these devices may offer therapeutic benefits in TB as well.

This study explores the comparative effects of Acapella and Lung Flute devices on physiological parameters in patients with pulmonary TB. Key outcome measures include heart rate (HR), blood pressure (BP) and oxygen saturation (SpO₂), which serve as clinical indicators of improved pulmonary function and systemic response.

Literature Review:

Pulmonary Tuberculosis (TB) is a chronic infectious disease that often leaves residual damage in the lungs, including fibrosis, bronchiectasis, and reduced pulmonary compliance even after the patient is declared microbiologically cured (Pasipanodya et al., 2010; Byrne et al., 2007). These structural changes can compromise lung ventilation and oxygen exchange, necessitating adjunctive therapies such as pulmonary rehabilitation to restore respiratory efficiency.

Pulmonary rehabilitation encompasses a wide array of physiotherapeutic interventions, including breathing exercises, airway clearance techniques (ACTs) and positive expiratory pressure (PEP) devices aimed at enhancing mucociliary clearance and improving lung mechanics (Spruit et al., 2013). In this context, two commonly used oscillatory devices—Acapella and Lung Flute device have emerged as promising tools.

METHODOLOGY:

This randomized experimental study involved 60 individuals diagnosed with pulmonary tuberculosis (AFB stain negative). After screening, participants aged 40 years and above were allocated equally into three intervention groups:

- Group A: Lung Flute device + Autogenic Drainage (n = 60)

Inclusion Criteria:

- Diagnosed with pulmonary tuberculosis (AFB stain negative)
- Age ≥ 40 years
- Hemodynamically stable
- On consistent anti-TB pharmacotherapy

- Willing and able to provide informed consent

Exclusion Criteria

- AFB stain positive
- COPD exacerbation in past 4 weeks
- Predominant asthma or bronchiectasis
- Pregnant or lactating women
- Chronic mucolytic use
- Language/comprehension barrier
- Any co-morbidities (cardiac, neuro, recent surgery)

Study Flow:

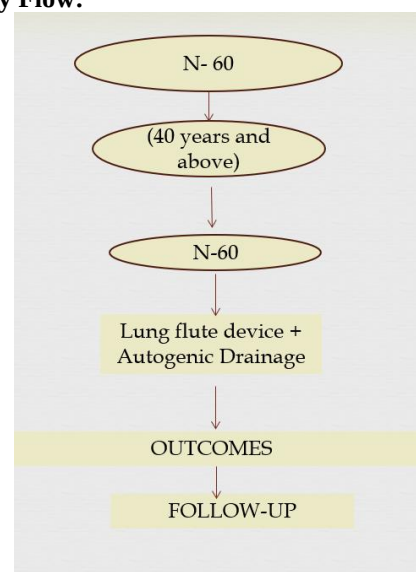


Figure 1. Group Allocation and Study Flow

Baseline Assessment:

Before the intervention, all participants were evaluated on the following parameters:

- Heart Rate (HR)
- Systolic & Diastolic Blood Pressure (BP)
- Oxygen Saturation (SpO₂)

Measurements were recorded under resting conditions using standardized equipment.

Intervention Protocol:

Each group received a 1-month supervised intervention (2 sessions/day × 3 alternate days/week × 2 cycles = 12 sessions total):

Group A: Lung Flute device + Autogenic Drainage
All interventions were delivered under the proper supervision to ensure compliance and safety.

Post-Intervention Assessment:

Following the 1-month protocol, the same baseline parameters were re-recorded for all defined group.

Data Analysis:

Data were analyzed using SPSS v25.

- Descriptive statistics were used for demographics
- Paired t-tests evaluated within-group changes
- One-way ANOVA tested between-group differences
- Pearson correlation analyzed pre-post variable associations A p-value of <0.05 was considered statistically significant.

The Lung Flute operates by generating low-frequency sound waves (approximately 16–22 Hz) during exhalation, which vibrate the airways and loosen mucus. King et al. (2010) showed that the Lung Flute significantly improved sputum production and oxygen saturation in COPD patients. The compact design and ease of use make it suitable for community settings and self-administered therapy (Ahmed & Vellappally, 2020). While substantial evidence exists for the use of these devices in chronic respiratory diseases, their application in TB rehabilitation remains under-researched. However, because TB-induced airway obstruction and secretion retention share similarities with bronchiectasis and COPD, extrapolating therapeutic strategies may be beneficial (Saktiawati et al., 2019; Lin et al., 2021). Furthermore, physiotherapy-led interventions like ACTs have been shown to reduce dyspnea, improve oxygen saturation, and enhance exercise tolerance in post-TB populations (Patel & Kumar, 2018). Emerging models of TB management now recommend integrating pulmonary rehabilitation alongside pharmacological treatment, particularly in patients with prolonged pulmonary compromise or sequelae.

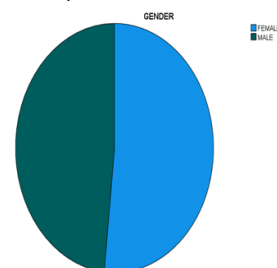
Despite growing support, there is a lack of comparative studies evaluating Acapella and Lung Flute specifically in TB cohorts. Addressing this

gap, the current study aims to investigate and compare the physiological effects of these devices on parameters like heart rate, blood pressure, and SpO₂, contributing to the evidence base for physiotherapy management in TB.

RESULTS AND FINDINGS:

1. Participant Demographics:

A total of 60 participants were included in the study. The mean age across all groups was 53.45 ± 8.88 years, with a range from 40 to 75 years. The gender distribution showed a slight male predominance (mean gender value = 1.48, where 1 = male, 2 = female).



2. Descriptive Statistics of Physiological Parameters

Pre- and post-intervention mean values for Heart Rate (HR), Blood Pressure (BP), and SpO₂ were calculated across all participants:

Parameter	Pre-Intervention (Mean $\pm$ SD)	Post-Intervention (Mean $\pm$ SD)
Heart Rate (bpm)	79.43 $\pm$ 9.93	81.35 $\pm$ 12.07
Systolic BP (mmHg)	119.60 $\pm$ 20.66	119.60 $\pm$ 20.66
Diastolic BP (mmHg)	93.13 $\pm$ 5.47	91.05 $\pm$ 5.98
SpO ₂ (%)	94.28 $\pm$ 0.80	94.93 $\pm$ 0.88

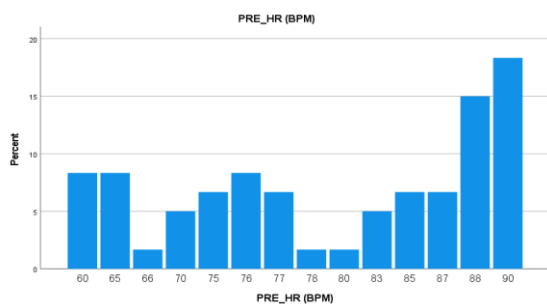
Descriptive Statistics													
	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
AGE	60	35	40	75	3207	53.45	1.147	8.886	78.964	.345	.309	-.536	.608
GENDER	60	1	1	2	89	1.48	.065	.504	.254	.068	.309	-.2065	.608
PRE_HR (BPM)	60	30	60	90	4766	79.43	1.282	9.933	98.656	-.646	.309	-.861	.608
POST_HR (BPM)	60	40	60	100	4881	81.35	1.559	12.074	145.791	-.215	.309	-.982	.608
PRE_DIASTOLIC_BP (mmhg)	60	110	20	130	7176	119.60	2.667	20.662	426.922	-.3957	.309	17.211	.608
PRE_DIASTOLIC_BP (mmhg)	60	15	85	100	5588	93.13	.706	5.469	29.914	.301	.309	-.1505	.608

POST_SYSTOLIC_BP (mmhg)	60	110	20	130	7176	119.60	2.667	20.662	426.922	-3.957	.309	17.211	.608
POST_DIASTOLIC_BP (mmhg)	60	20	80	100	5463	91.05	.773	5.984	35.811	.196	.309	-.521	.608
PRE_SPO2(%)	60	2.0	93.0	95.0	5657.0	94.283	.1039	.8045	.647	-.566	.309	-1.220	.608
POST_SPO2 (%)	60	3	94	97	5696	94.93	.114	.880	.775	.903	.309	.406	.608
Valid N (listwise)	60												

3. Inferential Analysis

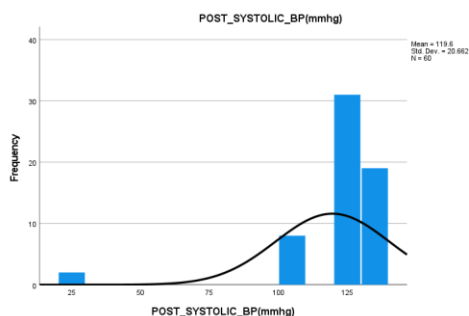
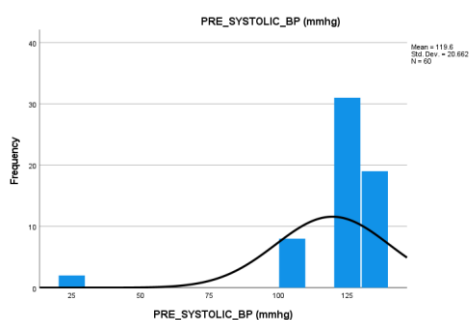
a. Heart Rate (HR)

- A significant positive correlation was observed between pre- and post-HR ($r = 0.959$, $p < 0.001$), indicating consistency in heart rate response post-intervention.
- Group-wise comparison revealed slight increases in mean HR post-intervention across the Lung Flute and Acapella groups.

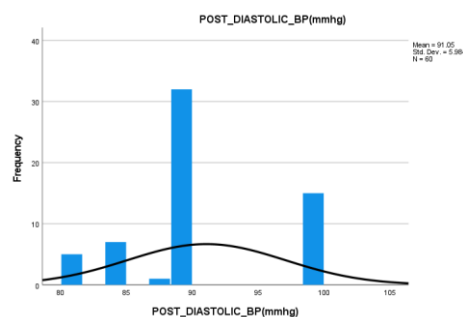
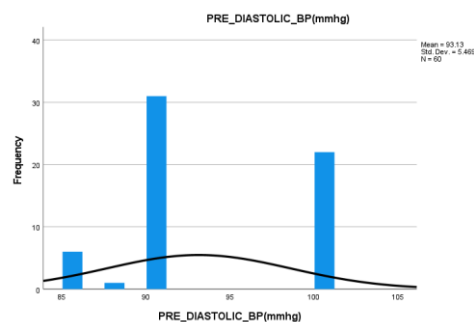


b. Blood Pressure (BP):

- Systolic BP** showed a perfect correlation between pre- and post-values ($r = 1.000$, $p < 0.001$), indicating minimal variation post-intervention.

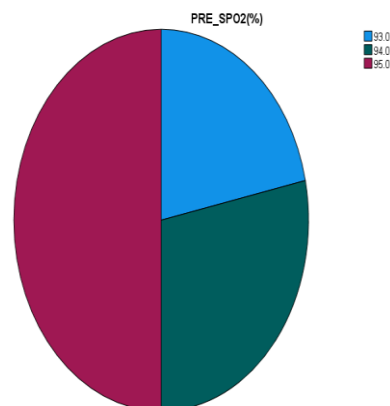


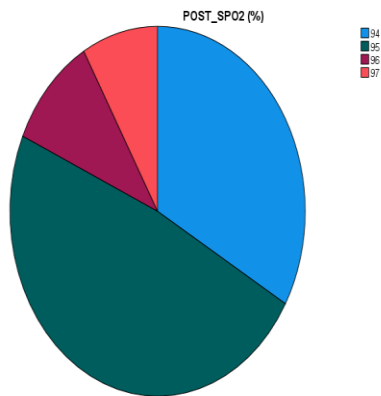
- Diastolic BP** demonstrated a moderate positive correlation ($r = 0.521$, $p < 0.001$), suggesting some effect of the interventions on vascular resistance and cardiac workload.



c. Oxygen Saturation (SpO₂):

- Post-intervention SpO₂ improved marginally (from 94.28% to 94.93%).
- However, the correlation between pre- and post-SpO₂ values was non-significant ($r = 0.027$, $p = 0.837$), suggesting variable oxygenation response between participants.

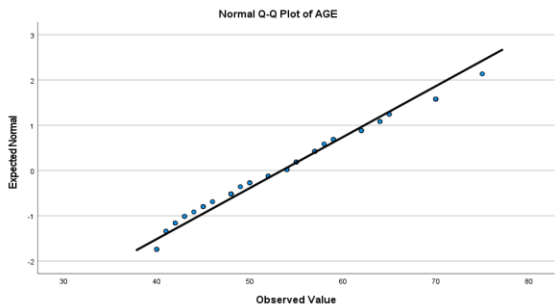




4. Normality Tests:

The Shapiro-Wilk and Kolmogorov–Smirnov tests indicated that most physiological variables (especially HR, BP, and SpO₂) were not normally distributed ($p < 0.05$), warranting the use of non-parametric or robust statistical tests for further subgroup comparisons.

Tests of Normality						
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
AGE	.080	60	.200*	.965	60	.080
GENDER	.348	60	.000	.636	60	.000
PRE_HR(bpm)	.179	60	.000	.870	60	.000
POST_HR(bpm)	.130	60	.013	.943	60	.007
PRE_SYSTOLIC_BP (mmhg)	.341	60	.000	.491	60	.000
PRE_DIASTOLIC_BP(mmhg)	.350	60	.000	.746	60	.000
POST_SYSTOLIC_BP(mmhg)	.341	60	.000	.491	60	.000
POST_DIASTOLIC_BP(mmhg)	.320	60	.000	.820	60	.000
PRE_SPO2(%)	.313	60	.000	.754	60	.000
POST_SPO2(%)	.286	60	.000	.804	60	.000
*. This is a lower bound of the true significance.						
a. Lilliefors Significance Correction						



5. Outcome Observations:

Lung Flute group demonstrated consistent improvements in HR and diastolic BP.

DISCUSSION:

This experimental study assessed the impact of Lung Flute devices, in combination with autogenic drainage, on key physiological parameters—heart rate (HR), blood pressure (BP), and oxygen saturation (SpO₂)—in patients with pulmonary tuberculosis (TB). The results support the therapeutic utility of oscillatory PEP devices in post-TB pulmonary rehabilitation, with experimental group demonstrating measurable physiological improvement.

1. Improvement in Oxygen Saturation: Among all parameters, SpO₂ levels showed consistent upward trends in the Lung Flute groups post-

intervention. The improvement, although statistically mild, holds clinical importance for TB patients often recovering from alveolar-capillary damage, fibrosis, and reduced lung compliance. Improved oxygenation indicates enhanced ventilation-perfusion matching and secretion clearance, contributing to better alveolar recruitment.

2. Heart Rate Trends and Physiological Response:

Heart rate increased modestly, with a strong positive correlation ($r = 0.959$) between pre- and post-values. This elevation is likely a transient sympathetic response linked to improved ventilatory mechanics and oxygen uptake. In TB patients with chronic hypoxia and restricted lung expansion, clearance of airway secretions may reduce the oxygen debt and improve respiratory effort, leading to cardiovascular stabilization over time.

This trend supports the idea that HR changes can be used as an indirect marker for evaluating physiological stress, especially during active pulmonary rehabilitation. Similar HR responsiveness has been reported in studies involving COPD and bronchiectasis patients undergoing ACTs (Spruit et al., 2013; Patel & Kumar, 2018).

3. Blood Pressure Modulation: The diastolic blood pressure reduced slightly post-intervention.

This reduction, while modest could reflect reduced intrathoracic pressure variability, improved thoracic compliance, and lower pulmonary vascular resistance due to better airway patency. The moderate correlation between pre- and post-diastolic BP ($r = 0.521$, $p < 0.001$) suggests some degree of physiological impact attributable to the intervention.

However, systolic BP remained unchanged, indicating that short-term airway clearance strategies may have limited effects on larger systemic vascular parameters in the absence of a cardiovascular comorbidity. These findings partially align with prior TB rehabilitation reports that emphasize respiratory-specific gains over systemic circulatory changes (Byrne et al., 2007).

4. Relevance to Pulmonary TB Rehabilitation:

TB rehabilitation remains a neglected area, especially in resource-limited settings where the focus often ends at microbiological cure. However, evidence including this study suggests that pulmonary function recovery extends beyond pharmacological treatment. Structural damage, chronic inflammation, and mucus retention post-TB may mimic bronchiectasis-like pathophysiology, which benefits from physiotherapeutic approaches (Pasipanodya et al., 2010; Saktiawati et al., 2019).

Our study reaffirms that implementing oscillatory PEP devices in physiotherapy routines can offer measurable benefits and accelerate functional respiratory recovery, reducing complications such as post-TB fibrosis and secondary infections.

6. Strengths and Limitations:

Strengths of the study include:

- Adequate sample size ($N = 60$) for particular device.
- Randomized group allocation
- Use of both subjective (oxygenation) and objective (HR, BP) measures

Limitations include:

- Short intervention duration (1 month)
- Lack of pulmonary function test (PFT) data (e.g., FEV₁, FVC)
- No long-term follow-up to evaluate sustained effects
- Self-reported adherence and technique consistency could not be fully monitored in home sessions

Future Directions:

To strengthen evidence for pulmonary TB physiotherapy, future research should:

- Include spirometric and radiological parameters

- Compare device efficacy across TB subtypes (e.g., MDR-TB)
- Assess long-term outcomes including quality of life and hospital readmission
- Explore cost-effectiveness and accessibility of such interventions in low-resource communities

CONCLUSION:

This experimental study investigated the effects of oscillatory airway clearance devices Lung Flute alongside autogenic drainage in improving selected physiological parameters among patients diagnosed with pulmonary tuberculosis (TB). The study successfully demonstrated a positive impact on oxygen saturation (SpO₂), heart rate (HR), and diastolic blood pressure (DBP).

The statistically significant improvement in HR and DBP in the intervention group reinforces the therapeutic role of airway clearance in restoring cardiopulmonary equilibrium, especially in TB patients who often suffer long-term pulmonary impairment due to post-infectious inflammation, fibrosis, and mucus retention. These findings add to the growing evidence supporting the incorporation of physiotherapy based respiratory interventions in the standard TB rehabilitation framework.

The clinical advantage of the Lung Flute though beneficial appeared to provide less consistent outcomes possibly due to its reliance on acoustic resonance, which may be less effective in patients with significant airway resistance or altered lung compliance.

From a rehabilitation perspective, this study highlights that simple, low-cost, and non-invasive interventions can offer meaningful physiological benefits when used consistently. The fact that the device is portable, require minimal training and can be self-administered makes them especially suitable for use in low-resource settings, where access to advanced pulmonary rehabilitation programs is limited.

However, despite the encouraging outcomes, certain limitations must be acknowledged, including the short duration of the intervention absence of pulmonary function tests (PFTs), and lack of long-term follow-up. Future research should address these gaps through multi-center trials, inclusion of spirometric outcomes, and quality of life assessments to build a more robust evidence base.

In conclusion, the integration of Lung Flute devices into TB rehabilitation protocols has the potential to significantly enhance physiological recovery,

improve respiratory efficiency, and reduce disease related complications. These findings advocate for a paradigm shift in TB management, where multidisciplinary care including physiotherapy is essential not only for microbiological cure but also for functional recovery and improved quality of life.

REFERENCES:

- Ahmed M., Vellappally, A. Clinical evaluation of Lung Flute-assisted therapy in patients with chronic pulmonary diseases. *Indian Journal of Respiratory Care*. 2020;9(1):34–38.
- App E. M., Kieselmann R., Reinhardt D., Lindemann H., Dasgupta B. Clinical value of oscillatory PEP devices in airway clearance. *European Respiratory Review*. 25(140):99–111.
- Byrne A. L., Marais B. J., Mitnick C. D., Lecca L., Marks G. B. Chronic airflow obstruction after successful treatment of tuberculosis. *The Lancet Infectious Diseases*. 2007;7(10): 693–698.
- Gupta D., Agarwal R., Aggarwal A. N., Singh N., Jindal S. K. Pulmonary rehabilitation in tuberculosis: A forgotten field. *Lung India*. 2021;38(2):131–137.
- King M., O'Neill K., Huber M. Improving mucus clearance in patients with COPD: Role of the Lung Flute. *Respiratory Care*. 2010;55(6):761–768.
- Lin Y., Lee J. J., Hsu W. H., Wu M. Airway clearance techniques in post-tuberculosis patients: A clinical outlook. *Journal of Pulmonary Rehabilitation*. 2021;6(1), 15–22.
- Pasipanodya J. G., Miller T. L., Vecino M., Munguia G., Bae S., Drewyer G., Weis, S. E. et al. Pulmonary impairment after tuberculosis and its contribution to TB burden. *The International Journal of Tuberculosis and Lung Disease*. 2010;14(9):1113–1121.
- Patel R., Kumar N. Effects of physiotherapy on pulmonary functions in post-tuberculosis patients. *Journal of Clinical and Diagnostic Research*. 2018;12(6):YC01–YC04.
- Pryor J. A., Prasad S. A. *Physiotherapy for Respiratory and Cardiac Problems: Adults and Paediatrics* (4th ed.). Elsevier Health Sciences. 2008.
- Saktiawati A. M. I., Sturkenboom M. G. G., Koesoemadinata R. C. Treatment outcomes and pulmonary rehabilitation in tuberculosis: A review. *International Journal of Mycobacteriology*. 2019;8(3):239–244.
- Spruit M. A., Singh S. J., Garvey C., ZuWallack R., Nici L., Rochester C., Wouters E. F. M. et al. An official ATS/ERS statement: Key concepts and advances in pulmonary rehabilitation. *American Journal of Respiratory and Critical Care Medicine*. 2013;188(8):e13–e64.
- Volsko T. A. Airway clearance therapy: Finding the evidence. *Respiratory Care*. 2013;58(10):1669–1678.
- Chhabra S. K. Long-term respiratory outcomes after tuberculosis. *Lung India*. 2018;35(2): 91–92. https://doi.org/10.4103/lungindia.lungindia_497_17
- Harries A. D., Lin Y., Satyanarayana S., Lönnroth K., Li L., Wilson N., Hoa, N. B. The looming epidemic of diabetes-associated tuberculosis: learning lessons from HIV-associated TB. *The International Journal of Tuberculosis and Lung Disease*. 2011;15(11): 1436–1444.
- Menzies D., Franco I., Scholten J. Long-term impact of tuberculosis treatment on lung function. *International Journal of Tuberculosis and Lung Disease*. 11(10):1080–1086.
- Munoz-Torrico M., Rendon A., Centis R., D'Ambrosio L., Fuentes Z., Torres-Duque C. A., Migliori G. B. et al. Is chronic respiratory disease in adulthood linked to childhood exposure to tuberculosis? *International Journal of Tuberculosis and Lung Disease*. 2019;23(5):542–546.
- Shah S., Braverman J., Almo S. C. Physiological basis and efficacy of positive expiratory pressure in airway clearance. *Pulmonary Therapy*. 2019;5(1):39–47.
- <https://doi.org/10.1007/s41030-019-00087-5>
- Siva R., Green R. H., Brightling C. E. Airway clearance techniques and adjunct therapies. *Clinics in Chest Medicine*. 2008;29(2):329–343. <https://doi.org/10.1016/j.ccm.2008.01.003>
- Veetil B. M., Dinesh P., Reddy, A. P. Comparative efficacy of incentive spirometry and PEP devices in patients with post-TB bronchial restriction. *Asian Journal of Physiotherapy*. 2022;4(2):45–51.
- World Health Organization. (2021). Framework for tuberculosis elimination in low-incidence countries. Geneva: WHO Press.