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LUNG FUNCTION IMPAIRMENT IN POST-TUBERCULOSIS PATIENTS

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Abstract

Post-tuberculosis lung disease (PTLD) has emerged as a significant contributor to chronic respiratory morbidity among individuals who have successfully completed anti-tuberculosis therapy. Despite microbiological cure, many patients continue to experience persistent structural and functional pulmonary impairments, which adversely affects their quality of life and functional capacity. This study was conducted to determine the prevalence, spirometeric patterns, and predictors of lung function impairment in post-tuberculosis patients, and to evaluate its association with functional exercise capacity. A cross-sectional analytical study was carried out in the Department of Pulmonology Jinnah Post Graduate Medical Centre, Karachi, a tertiary care hospital, including 200 patients aged 20–55 years who had completed standard anti-tuberculosis treatment. Data was collected using a structured proforma, and pulmonary function was assessed through spirometry following standardized guidelines. Functional capacity was evaluated using the six- minute walk test (6MWT), along with measurement of oxygen saturation before and after six-minute walk test. The findings revealed that a substantial proportion of patients exhibited abnormal spirometry patterns, with obstructive defects being the most common, followed by mixed and restrictive patterns. Patients with impaired lung function demonstrated significantly reduced six- minute walk distance and greater exercise-induced oxygen desaturation compared to those with normal spirometry.

1. INTRODUCTION

Tuberculosis (TB) has continued to be among the major infectious diseases in the world with significant morbidity and mortality, especially in developing nations with low and average income. Though great progress has been made in the diagnostic methodology and anti-tuberculosis therapy is very accessible even in most areas, the burden of TB remains very high. Historically, microbiological cure and completion of therapy have been used as the measure of success in the treatment of TB (Ivanova et al., 2023). Nevertheless, there is an increasing amount of evidence that a significant number of patients still experience long-term pulmonary complications despite successful treatment. All these chronic sequelae are collectively known as post-tuberculosis lung disease (PTLD), which is a condition that is currently being acknowledged as one of the primary issues of public health concerns (Musa et al., 2024).

The range of structural and functional abnormalities of the lungs covered by PTLD is rather broad. Pathophysiology of PTLD is complex and multifactorial as it is associated with continuing inflammation, fibrosis, airway remodeling, and destruction of lung parenchyma. Such pathological alterations usually lead to permanent limitation of lung functioning that could be obstructive, restrictive or combined on spirometry (Abdelaleem et al., 2022). Airway narrowing, bronchiectasis and small airway disease are often characterized by the presence of obstructive patterns and fibrotic changes and loss of lung volumes are the characteristics of restrictive defects. In most instances, the patient has a combination of all the two patterns indicating widespread and diffuse lung damage.

PTLD has clinical implications which are far-reaching. Chronic respiratory symptoms that are common in patients include persistent cough, dyspnea, decreased exercise tolerance and fatigue. These symptoms may severely affect everyday activity, efficiency of working, and the overall quality of life. In addition, PTLD has been linked to the high vulnerability to recurrent respiratory infections, hospitalization, and long-term disability (Odinaka et al., 2025). Nevertheless, PTLD is not appropriately diagnosed or identified, especially in health care facilities with limited resources, where testing of pulmonary function and specialized care is not readily available (Gai, Allwood, et al., 2023).

A central role of determining and defining PTLD is in spirometry, which forms a major diagnostic tool to evaluate the lung functioning of the body. It gives objective measurements like forced expiratory volume in one second (FEV 1), forced vital capacity (FVC) and FEV 1/FVC ratio that are important in categorizing ventilatory defects. Functional capacity assessment instruments like the six-minute walk test (6MWT) are also important in understanding the real-life consequences of the lung impairment by assessing the maximal capacity of exercise, as well as saturation of oxygen (Islam et al., 2025). The combination of these tests gives a clear picture of functional impairments of the post-TB patient.

Poor socioeconomic status, dwindled healthcare facilities, and poor systems of following up with treatment are yet another problem that contributes to the PTLD predicament in high TB burden countries such as Pakistan (Woldesemayat et al., 2025). Most patients fail to get regular check-ups upon completion of TB therapy, which creates failure in timely diagnosis and treatment. Moreover, biomass fuel smoke and air pollution, as well as the presence of poor nutrition, may also have a negative impact on worsening lung damage and deteriorate the outcomes (da Silva, da Silva Pinto, et al., 2025). These aspects show the necessity of a more global approach to TB treatment that is not just based on microbiological treatment but also in the form of long-term monitoring and pulmonary health control.

Since there is recent understanding of the prevalence of PTLD as an important contributor to the burden of chronic respiratory disease, there is an urgency to gain a deeper insight into prevalence, patterns and determinants (Hussain et al., 2024). It is important to determine the degree of lung functioning loss and related variables to prepare specific interventions and enhance patient outcomes. Thus, the research paper will compare the impairment of lung functions in patients with post-tuberculosis and determine the extent to which this affects functional exercise capacity and the key predictors related to unfavorable respiratory outcomes (Meghji et al., 2025).

Aim of the Study

To examine the occurrence and trends of lung function impairment in post-tuberculosis patients, determine important demographic and clinical predictors and determine the influence on functional exercise capacity, long-term respiratory health, pulmonary rehabilitation, development of specific management guidelines and overall quality of life.

Research Objectives

1. To ascertain the prevalence of lung function impairments in patients who had been treated with tuberculosis.

2. To determine the trends of spirometry patterns of obstructive, restrictive and mixed defects of ventilation.
3. The aim of the research was to assess the functional exercise capacity of post-tuberculosis patients with six-minute walk test.
4. To evaluate demographic and clinical predictors of impairment of lung functioning, including age, gender, and elapsed time after treatment.
5. To offer suggestions to institutions or programs(like National TB Programs) in managing the post-tuberculosis patients clinically, integrating the spirometary and functional exercise capacity assessment as a mandatory tools in post pulmonary TB patients for a proper long-term follow-up, treatment, pulmonary rehabilitation and in developing a sophisticated PTLD management guidelines.

2. Literature Review

2.1 Global Burden of Tuberculosis and Post-Tuberculosis Sequelae

Tuberculosis (TB) remains one of the key health issues of importance on a global scale, particularly in low- and middle-income nations. According to the words of world health organization(WHO), approximately 10.6 million individuals were infected with TB and almost 1.6 million died of the disease, in 2022(WHO, 2022). The global response to the decrease in TB incidence has not been successful, every year millions of individuals are infected and TB is one of the leading causes of mortality due to its infectious nature. Although microbiological cure is the main goal of TB treatment, there is growing evidence to show that it is not necessarily the case that recovery following infection is accompanied by complete restoration of lung health. Many TB survivors develop long-term pulmonary abnormalities which can last many years after treatment (Al-Hindawi et al., 2026). These post-tuberculosis lung diseases (PTLD) may present as chronic airflow obstruction, restrictive lung pattern, mixed ventilatory defects. These conditions do not only deteriorate the functioning of the lungs but also reduce the quality of life, reduce the physical capacity, and enhance healthcare use (Da Silva, de Lima, et al., 2025). The global burden of a disease that has not been previously understood is that a considerable percentage of the victims of TB acquired measurable lung impairment as a result. PTLD recognition has changed the management approach of TB, which meant that the focus on bacteriological cure was the goal, but the long-term functional and structural outcomes should also be considered. There is mounting focus in public health strategies on the need to monitor survivors with chronic respiratory complication especially in high burden countries. Unless these sequelae are addressed, there will be cumulative morbidity, workforce productivity may be impaired and the socioeconomic costs may be higher, which highlights the importance of post-treatment surveillance and intervention programs (Nkereuwem et al., 2023).

2.2 Patterns of Spirometric Impairment in Post-TB Patients

Spirometry offers an efficient and consistent technique to measure lung volumes and capacities and can be used to determine patterns of lung impairments in TB survivors. Research shows that airway obstruction is the most frequent defect observed in patients after TB, manifested as obstruction of the airways by chronic bronchial inflammation, bronchiectasis, and increased mucus secretions and defective muco-ciliary escalation. Obstructive patterns lead to a decrease in airflow, an increased exhalation period and the inability to clear the mucus in the airways. Ventilatory defects are also seen because of parenchymal fibrosis, scarring, and loss of lung volume which decreases the full expansion range of the lungs (Zawedde et al., 2024). There is an increasing description of mixed patterns, featuring elements of obstructive and restrictive defects implying concomitant airway and parenchymal pathology. These combined impairments have generally been linked to more serious illness and disability. The complexity of PTLD and the need to perform specific clinical evaluations are highlighted by the heterogeneity of spirometry patterns. Determining the nature of the impairment may inform specific interventions, such as pharmacologic treatment, physiotherapy, and pulmonary rehabilitation (Taylor et al., 2023). Besides knowledge of these patterns can help clinicians to anticipate the functional limitations, exacerbation risk, and

long-term outcomes of TB survivors. Local literature has demonstrated differences in the prevalence and the nature of spirometry defects that are dependent on factors related to severity of primary TB, delays in therapy, comorbidity and environmental pollutant exposure. In general, spirometry is a valuable research and clinical instrument in assessing the nature and extent of post-TB lung damage (Safareena et al., 2026).

2.3 Functional Exercise Capacity and Physical Limitations

The post TB lung disease does not restrict itself to structural changes only, it also has a major impact on functional exercise capacity of the patients. Six-minute walk test (6MWT) is a highly prevalent method of examining exercise tolerance and the test is the reflection of the combined effect of the pulmonary, cardiac, and musculoskeletal systems (Wang et al., 2025). Literature indicates that survivors of TB with abnormal spirometry especially those with mixed ventilatory defects have shorter six-minute walk distances (6MWD) and are susceptible to oxygen destruction during exercise. The functional capacity may be reduced to the point of causing severe limitations in the daily activities, occupational performance, and social participation. Exercise limitation can be seen as a complex of ventilatory limitation, difficulty in exchange of gases at alveoli-capillary complex, decrease in cardiopulmonary reserve, a state of chronic inflammation and deconditioning of skeletal muscle. Constant fatigue, dyspnea and reduced endurance also stimulate reduced physical performance (Bisson et al., 2025). Noteworthy, the outcome of 6MWT has a predictive value on morbidity and mortality in chronic respiratory diseases and gives clinicians a useful prognostic tool. Stratification of risk, disease progression and timely interventions can be achieved by periodically determining functional capacity, which will help the healthcare provider to implement timely interventions. Functional assessment also provides information about the total burden of PTLD measurement beyond spirometry which illustrates the life burden of patients with lung impairment (van der Zalm et al., 2024).

2.4 Demographic and Clinical Predictors of Lung Impairment

Several demographics, clinical and socio-environmental characteristics impact the progression and the severity of post-TB lung disease. The most influential predictor is age, an older patient is more likely to have severe lung impairment caused by a reduced regenerative capacity, loss of alveolar elasticity, and prone-ness to fibrosis. The male gender has also been linked to increased risk which may also be linked to increased occupational exposures to dust and pollutants, disparities in smoking, and late healthcare-seeking practices (Nguyen et al., 2024). Poor nutrition and low body weight worsen repair and recovery of the lungs, whereas long periods since treatment can result in progressive structural alterations, such as airway or parenchymal fibrosis and bronchiectasis. Environmental exposures, such as smoke of biomass, urban air pollution and work irritants, are also some of the driving factors in the continuation of inflammation and airflow blockage (Silva et al., 2025). Lower socioeconomic status and illiteracy are also hindrances in the understanding the disease thus negatively influencing the PTLD outcome. Learning about these predictors is necessary to recognize the high-risk groups of patients and apply specific post-treatment surveillance and rehabilitation measures. Timely interventions can be promoted through early detection and risk stratification to reduce long term disability and enhance functional outcomes of TB survivors.

2.5 Pulmonary Rehabilitation and Management Strategies

Pulmonary rehabilitation is progressively accepted as one of the pillars of managing the post-TB lung disease. Formal rehabilitation includes exercise training (aerobic exercise,endurance training, upper and lower limb strengthening), breathing exercises(thoracic expansion exercise, pursed lip breathing, diaphragmatic breathing), airway clearance techniques (postural drainage, chest physiotherapy, active cycle of breathing techniques), education(disease understanding, proper inhaler techniques,energy conservation),

nutritional and psychological support and oxygen therapy guidance. There is evidence that these interventions have a positive effect on exercise tolerance, dyspnea, quality of life, and functional decline. Inspiratory muscle training and endurance-based exercises can be used as part of personalized rehabilitation strategies in patients with severe spirometry impairment to address deficits. De-conditioning, fatigue and decreased physical activity are other secondary effects of PTLD that pulmonary rehabilitation treats. The introduction of rehabilitation in the post-TB care courses can help prevent long-term morbidity and improve patient self-management and decrease health care expenditures (Sinha et al., 2025). Home-based exercises, community physiotherapy and simple functional assessments are simple resource-based strategies, which may be used as substitutes of full-scale rehabilitation programs in resource-limited settings (Alene et al., 2024). Rehabilitation as part of the post-TB care underlines the change towards more bacteriological-oriented treatment to survivor-oriented care due to the more general effects of the TB on physical, psychological, and social health (Nkereuwem et al., 2024).

2.6 Gaps in Literature and Rationale for the Study

Although there is an increase in awareness of the post-TB lung disease, there are notable gaps in research. Studies suffer because of small sample sizes, single-center recruitment, cross-sectional designs and lack of non-standardized spirometry protocols and thus limit the externalization of findings. In addition, longitudinal information on the course of development of lung impairment, exercise capacity, and functional limitations is lacking (Bansal et al., 2024). The relationship between structural changes in the lung and functional outcomes is not clearly known, especially in a heterogenous population where there is a difference in socioeconomic and environmental exposures. The integration of functional assessments, rehabilitation and long-term follow-up are also frequently not considered in existing research to form a part of the post-TB care model. These gaps should be addressed to establish evidence-based clinical practices, effective health-based policies and complete survivor-centered care models (Xing et al., 2023). Comprehensive, multidimensional research regarding the post-TB lung function, predictors of the impairment and the functional capacity can offer practical recommendations to the clinicians and policymakers, which will eventually benefit the quality of life and long-term outcomes of TB survivors.

3. Methodology

3.1 Research Design

The objective of this study was to conduct an analytical cross-sectional non experimental study that would assess the lung functional impairment among patients who had successfully undergone therapy of pulmonary tuberculosis (Silva et al., 2023). The selection of a cross-sectional design was due to the possibility to evaluate the extent, trend and burden of post- TB lung dysfunction at a given time, which could be of great epidemiological interest. Its design allows measuring various variables at the same time such as spirometry parameters, exercise capacity, demographic characteristics, and clinical history, which allows conducting a thorough analysis of the factors related to post-TB lung impairment (Byrne et al., 2023). Through the application of this method, the study will be able to create a baseline data that will be used in terms of future longitudinal studies and intervention strategies (Jagadeesh et al., 2025). The study took place in a tertiary care facility that is a referral center in terms of pulmonary diseases, which makes it possible to access a representative sample of patients with different severity of the disease and the history of treatment. The research design was designed in a way to reduce bias through the presence of clear inclusion and exclusion criteria, standard data collection procedures and the validated measurement instruments. Patterns that might point to the long-term risks of complications with respiratory problems could also be identified with the help of the cross-sectional design that is essential to developing the programs of post-TB care and rehabilitation plans (Govindaswamy et al., 2025). The approach to methodology fits the study objectives of determining the impairment of the

lung functioning, the factors that determine it, and the actionable data to be presented to facilitate clinical treatment.

3.2 Data Collection

The methods used to collect the data were a combination of structured interview, reviewing medical records, and objective clinical evaluation. The first demographic and clinical data collection was obtained in a face-to-face interview with the participants which included age, gender, weight, address ethnicity, occupation, educational status, rural and urban dwelling, family monthly income, smoking status, comorbidities, history of TB treatment and length of time since treatment was taken. To identify TB diagnosis, treatment regimen, and reported complications throughout the course of treatment, patient medical records were reviewed. Spirometry was used to evaluate the lung function, in accordance with the standard procedures suggested by American Thoracic Society(ATS)/European Respiratory Society(ERS) . Spirometry data were the forced vital capacity(FVC), forced expiratory volume in the first second (FEV1), FEV1/FVC ratio and peak expiratory flow rate (PEFR). The participants did at least three acceptable and reproducible maneuvers on each of them, and the best values were stored and analyzed (Seo et al., 2024). The six-minute walk test (6MWT) was the exercise capacity assessment tool that was done in a standardized corridor according to the standard recommendations to determine the distance covered, oxygen saturation levels pre and post six-minute walk test. The pre-designed collection forms were used to record data in a systematic manner, which made them consistent and complete. Calibration of spirometry equipment, employee training, and regular data accuracy checks were some of the measures of quality control (Thoker et al., 2023).

3.3 Sampling and Participants

The research employed non-probability convenience sampling method to sample outpatients and inpatients who full filled the inclusion criteria. Eligible subjects were adults (20-55years old who were non smokers) about two hundred(200) participants who had completed a complete course of anti-tuberculosis treatment(6 months of ATT) at least six months before the time when the trial commenced. Patients who have active TB, chronic diseases like Diabetes, hypertension, valvular heart diseases, ischemic heart disease, chronic liver disease, cardiomyopathy, heart-failure, chronic renal disease, known chronic respiratory illness(asthma,COPD,ILD etc) that is not related to TB, or severe comorbidities which may independently influence lung function, patients with contraindications to spirometary and who refused to give consent to participate were excluded. The sample size was calculated in relation to feasibility and load of patients in a hospital. This was done by using convenience sampling to minimize selection bias and all eligible patients(in and outpatients) were invited to join the study until the required sample size was obtained. This method provided wide coverage of age, sex, and the severity of the disease. All the participants were informed by the written informed consent prior to enrollment, and it stressed the voluntary involvement and the possibility of dropping out at any point. Both male and female patients were included as the population of the study and an attempt was made to encompass the diversity in demographics so that the research could have an increased generalizability (Gai, Cao, et al., 2023).

3.4 Data Analysis

The data were entered and analyzed into IBM SPSS statistics version 20. Testing of the normality of continuous variables was carried out using Shapiro Wilk test. Normally distributed variables had their means of standard deviation used as a means of summarizing and non-normally distributed variables had their means of median and interquartile range as a means of summarizing. Categorical variables were represented in terms of frequencies and percentages.

Independent samples t-test/Mann Whitney U test was used in the analysis of the variables with and without lung functional impairment in continuous variables and chi-square used in categorical variables. The impairment of the lung functions was found to be related to the factors which were calculated using the logistic

regression analysis method. The Univariate analysis of variables provided a p-value that was lower than 0.15 and was entered in a Multivariate logistic regression model. Adjusted odds ratios with 95 percent confidence were calculated and the significance of the statistic was set at a p- value under 0.05.

3.5 Ethical Considerations

The institutional ethical review board gave the study an ethical approval before the study was initiated. Informed consent was obtained in writing by all the participants who had been given detailed information about the objectives of the study, procedures, risks, and benefits. Personal and medical data were kept confidential . The participants were made aware of the fact that they were free to quit study at any time without facing any negative consequences.The research was conducted in accordance with the principles provided in the Declaration of Helsinki. How the participants date was handled was clearly communicated and all the sensitive information was protected by de-identifying the data and secure storage system.

4. Findings and Results

4.1 Introduction

This chapter presents the results of the statistical tests that were conducted to determine the prevalence, trends and predictors of the impairment of lung functions in patients who received treatment to cure pulmonary tuberculosis. On the sample of 200 participants the data was processed with the help of IBM SPSS Statistics version 20. Findings are described using descriptive statistics, spirometric patterns, results of functional assessment, bivariate and multivariate logistic regression. They have tables and figures to depict findings.

4.2 Demographic Characteristics

A total of 200 patients with previously treated pulmonary tuberculosis were included in the study. Among the participants, 124 (62%) were males and 76 (38%) were females, indicating a male predominance in the study population (Table 1). The average age was 43.1 years of age with a standard deviation of 11.4 years, and the average body weight was 61.5kg/m with standard deviation of 9.6kgs.

Regarding the Educational status 132 patients were literate(66%) where as 68 patients(34%) were illiterate. In terms of residential distribution, 114 patients (57%), were urban and 86 patients (43%) were rural dwellers.

The ethnic distribution showed Urdu-speaking (mohajir) participants (32%), Pathans (26%), Sindhi (20%) , Baloch (12%) and Kashmiri (10%) mentioned in Figure 2. The socioeconomic status showed that 82 patients (41%) belonged to lower socioeconomic class, 64 patients (32%) of middle class, 38 patients (19%) of upper middle class and 16 patients (8%) upper class(Figure 3).

Table 1: Gender Distribution of the Study Population (n = 200)

Gender	Frequency	Percentage
Male	124	62%
Female	76	38%
Total	200	100%

Figure shows the male predominance due to greater number of males were enrolled depicting males seek more medical attention compared to the females due to patriarchal social fabric.

4.3 Spirometry Findings

A spirometery revealed that 146 patients (73%) had an abnormal pulmonary function and 54 patients (27%) had normal spirometry. Among the abnormal spirometric patterns, Obstructive lung disease was most common observed in 82 patients (41%) followed by mixed ventilatory defects in 36 patients (18%) and restrictive lung disease in 28 patients (14%) . The findings indicate that spirometric impairment is highly prevalent among patients with post tuberculosis lung disease with airflow obstruction representing the predominant abnormality shown in the table 2.

Table 2: Distribution of Spirometry Patterns Among Post-Tuberculosis Patients

Spirometry Pattern	Frequency	Percentage
Obstructive	82	41%
Restrictive	28	14%
Mixed	36	18%
Normal	54	27%
Total	200	100%

4.4 Functional Exercise Capacity

Functional exercise capacity was assessed using the Six-Minute Walk Test(6MWT). The overall mean six-minute walk distance (6MWD) among the participants was 420.8 with a standard deviation of 84.6 meters which is lower than the expected normal reference range for healthy adults. When analyzed according to gender, male participants achieved a mean walking distance of 436.5 ± 82.3 meters, while female participants achieved a mean walking distance of 395.2 ± 79.6 meters. The findings indicated that males have slightly greater exercise capacity compared to females shown in the table 3.

Table 3: Six-Minute Walk Distance According to Gender

Gender	Mean 6MWD (m)
Male	436.5 ± 82.3
Female	395.2 ± 79.6

The males recorded a higher 6MWD than the females in all the spirometric categories.

4.5 Oxygen Saturation Before and After 6MWT

Oxygen saturation was measured both at rest and immediately after completion of six-minute walk test. The mean resting oxygen saturation (SpO2) was 96.3 ± 1.6% while the post exercise oxygen saturation (SpO2) decreased to 93.1 ± 2.3%, which showed an average desaturation of oxygen of 3.2% during the test, indicating patients with post-tuberculosis lung disease experience exercise-induced oxygen desaturation (Table 4).

Table 4: Oxygen Saturation Before and After 6MWT

Parameter	Mean Value
Resting SpO_2	96.3 ± 1.6%
Post-6MWT SpO_2	93.1 ± 2.3%
Oxygen Desaturation	3.2%

4.6 Comparison of Functional Exercise Capacity According to Spirometry Pattern

Comparison of six-minute walk distance across spirometric groups demonstrated a progressive decline in walking distance with increasing severity of ventilatory impairment.

Patients with normal spirometry achieved the highest mean walking distance (472 ± 70 meters). In comparison, patients with obstructive lung disease walked an average distance of 405 ± 80 meters, while those with restrictive defects walked 388 ± 75 meters. The lowest walking distance was observed among patients with mixed ventilatory defects (360 ± 72 meters). Shown in table 5.

Table 5: Six-Minute Walk Distance According to Spirometry Pattern

Spirometry Pattern	Mean 6MWD (m)
Normal	472 ± 70

Obstructive	405 ± 80
Restrictive	388 ± 75
Mixed	360 ± 72

ANOVA One-way ANOVA was used to establish a significant difference in 6MWD among the groups ($F = 14.72$, $p < 0.001$).

4.7 Comparative Analysis Between Gender, Lung Disease Type and 6MWD

Further comparative analysis revealed that male patients achieved higher six-minute walk distances compared with female patients across all spirometric categories. The difference in walking distance was most pronounced among patients with mixed ventilatory defects where females demonstrated the greatest reduction in exercise capacity. (Table 7).

Table 6: Comparison of Gender, Lung Disease Type and Six-Minute Walk Distance

Spirometry Pattern	Male 6MWD (m)	Female 6MWD (m)	Mean Difference (m)	P-value
Normal	485 ± 68	455 ± 65	30	0.018*
Obstructive	420 ± 76	382 ± 72	38	0.022*
Restrictive	400 ± 70	368 ± 68	32	0.031*
Mixed	372 ± 69	348 ± 66	24	0.041*

*P < 0.05 is statistically significant

4.8 Predictors of Lung Function Impairment

Multivariate logistic regression results were able to identify several independent predictors of lung impairment. The patients who were at higher risk of lung function impairment were those with low socioeconomic status (OR = 2.14, p = 0.01), advanced age >40 years (p =0.003), illiterate (OR = 1.72, p = 0.03), rural residence (OR = 1.85, p = 0.02) and lower body weight (<60 kgs) (OR = 2.36, p = 0.004). Lung function Impairment was not associated with ethnicity significantly (p = 0.21) (Table 6).

Table 7: Multivariate Logistic Regression Analysis for Predictors of Lung Function Impairment

Predictor Variable	Adjusted OR	95% CI	p-value
Low socioeconomic status	2.14	1.21 – 3.78	0.01*
Illiteracy	1.72	1.05 – 2.82	0.03*
Rural residence	1.85	1.09 – 3.12	0.02*
Body weight <60 kg	2.36	1.33 – 4.19	0.004*
Ethnicity	1.12	0.74 – 1.69	0.21

*P < 0.05 is statistically significant

4.9 Effect Size Analysis of Functional Impairment

Effect size (d (Cohen) analysis) has shown that spirometry impairment had a strong influence on 6MWD and mixed defects (d = 1.28), restrictive defects (d = 0.96) and obstructive defects (d = 0.82) (Table 8).

Table 8: Effect Size Analysis of Differences in 6MWD

Comparison	Mean 6MWD Normal (m)	Mean 6MWD Comparison Group (m)	Mean Difference (m)	Cohen's d	95% CI
Normal vs Obstructive	472 ± 70	405 ± 80	67	0.82	0.48 – 1.16
Normal vs Restrictive	472 ± 70	388 ± 75	84	0.96	0.60 – 1.32
Normal vs	472 ± 70	360 ± 72	112	1.28	0.92 –

Mixed					1.64

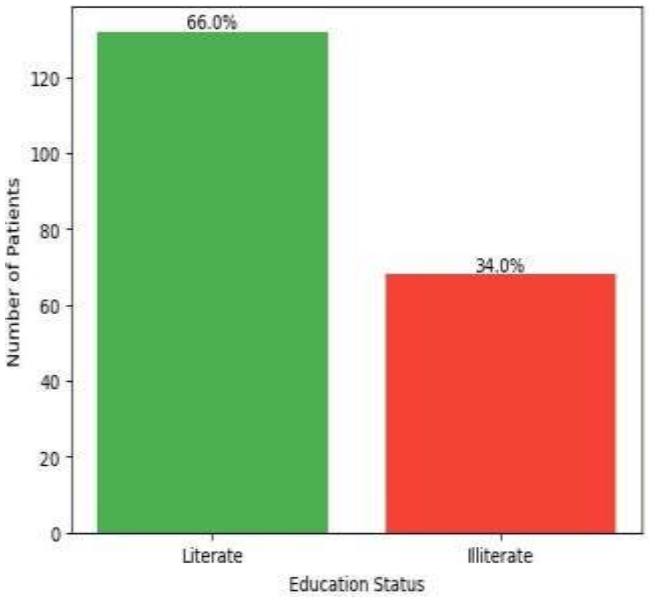

Figure 1: Education Status of study participants Table 8.

Association Between Age And Lung Function Impairment

Variable	Impaired (%)	Normal (%)	p-value
Age Group			
<40 years	48 (45.7)	57 (54.3)	0.003
>40 years	70 (73.7)	25 (26.3)	

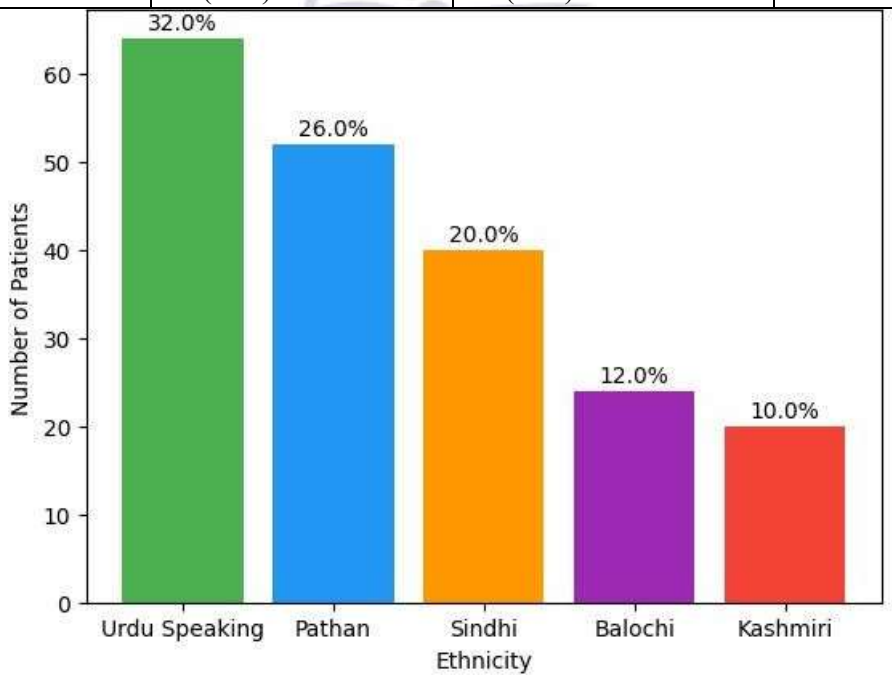

Figure 2: Distribution of study subjects according to their ethnicity

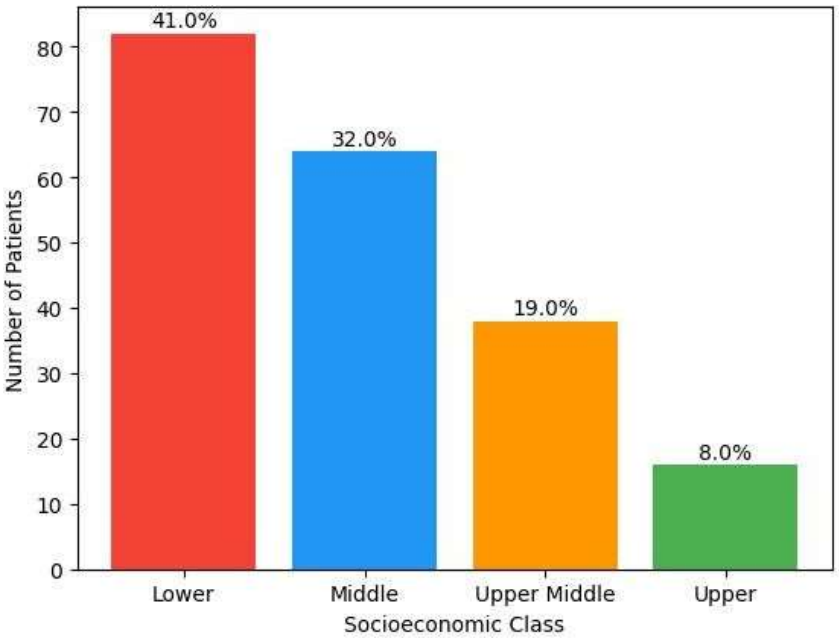

Figure 3: Distribution of study subjects according to their socioeconomic status

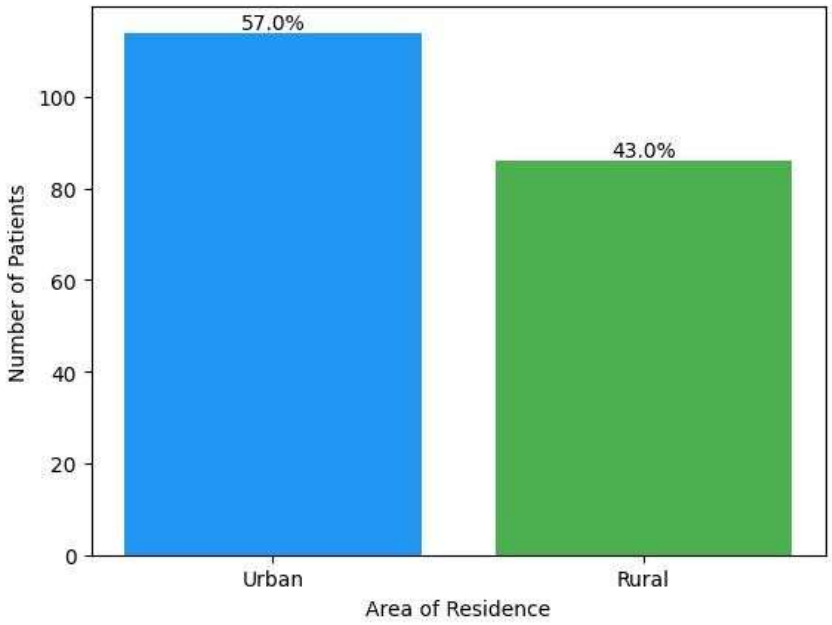

Figure 4: Distribution of study subjects according to their area of residence

Conclusion

The research paper illustrates that the impairment of lung functioning is an adverse clinical outcome that is prevalent in patients who have received treatment (6 months of ATT) for the pulmonary tuberculosis. Spirometry examinations showed that 73% of the participants showed abnormal lung functioning with obstructive and mixed ventilatory defects were the most common. These ventilatory defects were strictly interrelated with lower functional exercise capacity that was assessed by the six-minute walk test (6MWT) which points to the practical consequences of the post-TB lung disease on the daily routine, occupational

productivity, financial cost (of PTLD treatment), social participation, psychological well-being and quality of life of patient and these can be mitigated by incorporating an annual or two yearly spirometric and functional exercise capacity assessment of PTLD patients. Integrating the annual or two yearly assessment of post-TB lung disease patients could ensure the development and endorsement of PTLD management guidelines including timely pharmacological therapy and rehabilitational measures thus lessening the morbidity and mortality posed by PTLD patients. Multivariate analysis showed that low socioeconomic status, illiteracy, rural dwelling and lower body weight and increasing age (>40) years, male gender, longer interval after treatment and lower exercise capacity were independent predictors of lung dysfunction which means that post-TB pulmonary sequelae is multifaceted. These results indicate the need to perform spirometry and functional assessment of the survivors of the TB in the routine, to diagnose the residual impairment in the early stages and make appropriate interventions. Pulmonary rehabilitation together with exercise training and long-term follow-up inclusion into post-TB care can enhance functional outcome, lower morbidity as well as improving the quality of life. In general, the article supports the importance of adopting a survivor-based model of TB management to go beyond microbiological treatment to support long-term respiratory health.

Future Work

The longitudinal studies to monitor lung functions and exercise capacities in post-TB patients over time should be considered as further studies to comprehend pulmonary sequelae progression. Additional pulmonary function tests including diffusion capacity, measurements of lung volumes, and high-resolution imaging may offer more perspective on the structural-functional relationship of post-TB lung disease. To increase the generalization of the results and to determine the population-specific risk factors, multi-center studies involving more and more diverse populations are necessary. It is also justified to conduct interventional studies to investigate the effectiveness of these three interventions (i.e. pulmonary rehabilitation, pharmacological therapy, and lifestyle modifications) in terms of functional recovery. Also studies are needed on the psycho-social and socioeconomic consequences of chronic post-TB lung impairment to guide the overall care interventions. Creating predictive models integrating demographic, clinical and functional variables could help clinicians to reduce morbidity, improving patient and population quality of life and enhance early risk stratification and individualized management of post-TB care.

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