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# Post-tuberculosis respiratory impairment in Gambian children and adolescents: A cross-sectional analysis

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## Abstract

**Background:** Although post-tuberculosis lung disease (PTLD) is a known consequence of pulmonary tuberculosis (pTB), few studies have reported the prevalence and spectrum of PTLD in children and adolescents.

**Methods:** Children and adolescent (≤19 years) survivors of pTB in the Western Regions of The Gambia underwent a respiratory symptom screening, chest X-ray (CXR) and spirometry at TB treatment completion. Variables associated with lung function impairment were identified through logistic regression models.

**Results:** Between March 2022 and July 2023, 79 participants were recruited. The median age was 15.6 years (IQR: 11.8, 17.9); the majority, 53/79 (67.1%), were treated for bacteriologically confirmed pTB, and 8/79 (10.1%) were children and adolescents living with HIV. At pTB treatment completion, 28/79 (35.4%) reported respiratory symptoms, 37/78 (47.4%) had radiological sequelae, and 45/79 (57.0%) had abnormal spirometry. The most common respiratory sequelae were cough (21/79, 26.6%), fibrosis on CXR (22/78, 28.2%), and restrictive spirometry (41/79, 51.9%). Age at TB diagnosis over ten years, undernutrition and fibrosis on CXR at treatment completion were significantly associated with abnormal spirometry ($p$ = .050, .004, and .038, respectively).

**Conclusion:** Chronic respiratory symptoms, abnormal CXR, and impaired lung function are common and under-reported consequences of pTB in children and adolescents. Post-TB evaluation and monitoring may be necessary to improve patient outcomes.

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**KEYWORDS**
childhood tuberculosis, lung function, post-tuberculosis, respiratory impairment, sequelae, spirometry

## 1 | INTRODUCTION

Tuberculosis (TB) continues to impose a significant global health burden, with 10.6 million new cases and 1.6 million deaths reported in 2022.[1] Even though up to 85% of persons treated for new pulmonary TB (pTB) achieve treatment success, the issues of potentially long-lasting consequences for the health and well-being of TB survivors have recently gained increasing attention.[2–5] Emerging evidence from mostly adult studies has suggested that people previously treated for pTB continue to experience long-term respiratory impairment even years after successful treatment, leading to substantial post-TB morbidity and mortality.[6–9] Therefore, it is equally important to evaluate respiratory health and overall well-being after TB treatment in children and adolescents who are in a critical period of their lung development.[10]

A few published pediatric studies also suggest that children treated for pTB continue to experience ongoing respiratory health challenges, even after completing treatment and being declared cured.[11–13] Childhood pTB survivors have more frequent respiratory symptoms, significantly lower lung volumes, and more than three-fold increased odds of lung function impairment compared to healthy, age-matched children who had never been treated for TB.[11] Furthermore, a recent prospective birth cohort study highlighted persistent respiratory symptoms and growth impairment in post-TB survivors, emphasizing the long-term impact of early-life pTB on child health.[12]

Based on the still scarce existing literature, between 1% and 49% of pediatric TB survivors have post-TB respiratory sequelae characterized by persistent respiratory symptoms, radiological sequelae, or abnormal spirometry.[11–14] Moreover, the current definition of post-TB lung sequelae in the literature is quite heterogeneous, leaving room for subjectivity. There is need for a comprehensive minimum case definition for pediatric post-TB lung disease (PTLD) that captures the different disease phenotypes and can be useful in research and clinical practice.[2] Additionally, more data are needed to ascertain the long-term burden of PTLD.[2,11]

As proposed during the first international post-TB symposium, we defined pediatric PTLD as chronic respiratory impairment measured using chronic or recurrent respiratory symptoms, abnormal chest X-ray (CXR), and abnormal spirometry occurring alone or in combination.[2] The Gambian *Childhood TB Sequel* study set out to define the spectrum of PTLD in Gambian children and adolescents at treatment completion and assess the evolution of PTLD over the 12 months posttreatment.[15] Our aim in this paper is to describe the baseline characteristics of the *Childhood TB Sequel* cohort. We aimed to describe their respiratory symptoms, CXR findings, and spirometry characteristics and to identify the factors associated with abnormal respiratory function after TB treatment.

## 2 | METHODS

### 2.1 | Study design and participants

We conducted a cross-sectional descriptive analysis of participants at enrollment into the *Childhood TB Sequel* study, an ongoing prospective cohort study in the Western Regions of The Gambia.[15] Using the treatment registers at the 20 Gambia National Leprosy and Tuberculosis Control Programme (NLTP) clinics in the Western Regions 1 and 2, where the majority of the notified TB cases in The Gambia are treated,[16] we identified children and adolescents aged 19 years and below in the final month of antituberculous therapy for bacteriologically confirmed or clinically diagnosed (unconfirmed) pTB. Following successful outcome classification as *cured* or *treatment completed* by the Gambia NLTP, these children and adolescents were referred to our study clinic for screening and enrollment. We consecutively enrolled all eligible children and adolescents who presented within 6 weeks of treatment completion, following informed consent from their parents/legal caregivers and assent from children aged >7 years.

### 2.2 | Procedures

Study visits were conducted at the childhood TB research clinic of the Medical Research Council Unit The Gambia at the London School of Hygiene & Tropical Medicine (MRCG at LSHTM). Clinical information, including current self- or parent-reported symptoms derived from the St George's Respiratory Questionnaire,[17] recent and previous TB history were recorded during the enrollment visit. We also obtained a self-reported smoking history and environmental exposure to tobacco smoke and biomass fuel. Anthropometric measurements were calculated using the WHO 2007 reference standards.[18] Underweight and stunting were defined as body-mass-index-for-age (BAZ) and height-for-age z-scores (HAZ) less than −2 SD for age and sex, respectively.

A CXR was performed for each subject and interpreted by two independent clinicians (EN and BN) experienced in pediatric pTB. The clinicians were unaware of the symptoms or spirometry results of the subjects before CXR interpretation. Where there were disagreements in the presence or type of radiological abnormality, a third reader (ANF) was used to resolve discrepancies.

We performed spirometry for all children above 4 years using an Easy on-PC portable spirometer (ndd Medical Technologies, Zurich, Switzerland). Spirometry was performed by trained and experienced technicians and followed the American Thoracic Society (ATS)/European Respiratory Society (ERS) guidelines.[19] The z-scores for the Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 s ($FEV_1$) and the $FEV_1$/FVC ratio were calculated using the African American reference ranges of the Global Lung Function Initiative 2012 (GLI-2012) reference equations, which has shown to be best fit for the Gambian population.[20] The pattern of spirometry was defined using the 2022 ERS/ATS guideline.[21]

All children diagnosed with TB in The Gambia are routinely tested for HIV. For participants whose HIV status was unknown, we did a rapid HIV test followed by a confirmatory test (PCR for children below 18 months or HIV ELISA for children ≥18 months) if the rapid test was positive.

## 2.3 | Statistical methods

Every year, an average of 90 incident TB cases in children and adolescents are notified in the Western Regions 1 and 2 of The Gambia. Consistent with previous results in our population, we assumed a population prevalence of abnormal lung function of 38.5%,[11] and a finite population size of 90 in 1 year, a sample size of 73 allowed us to estimate the prevalence of respiratory impairment with a margin of error of less than 5% with 95% confidence.

For the analysis, we included only participants who could perform spirometry. Additionally, based on previously reported data, we classified self-reported illness duration into two categories: ≤4 weeks and >4 weeks.[22] Medians (IQR) and proportions were used as appropriate to describe the baseline, clinical and respiratory characteristics. We used Chi-square, Fisher's exact, or Mann-Whitney U tests to compare between groups as appropriate. Using univariable logistic regressions, we investigated the association

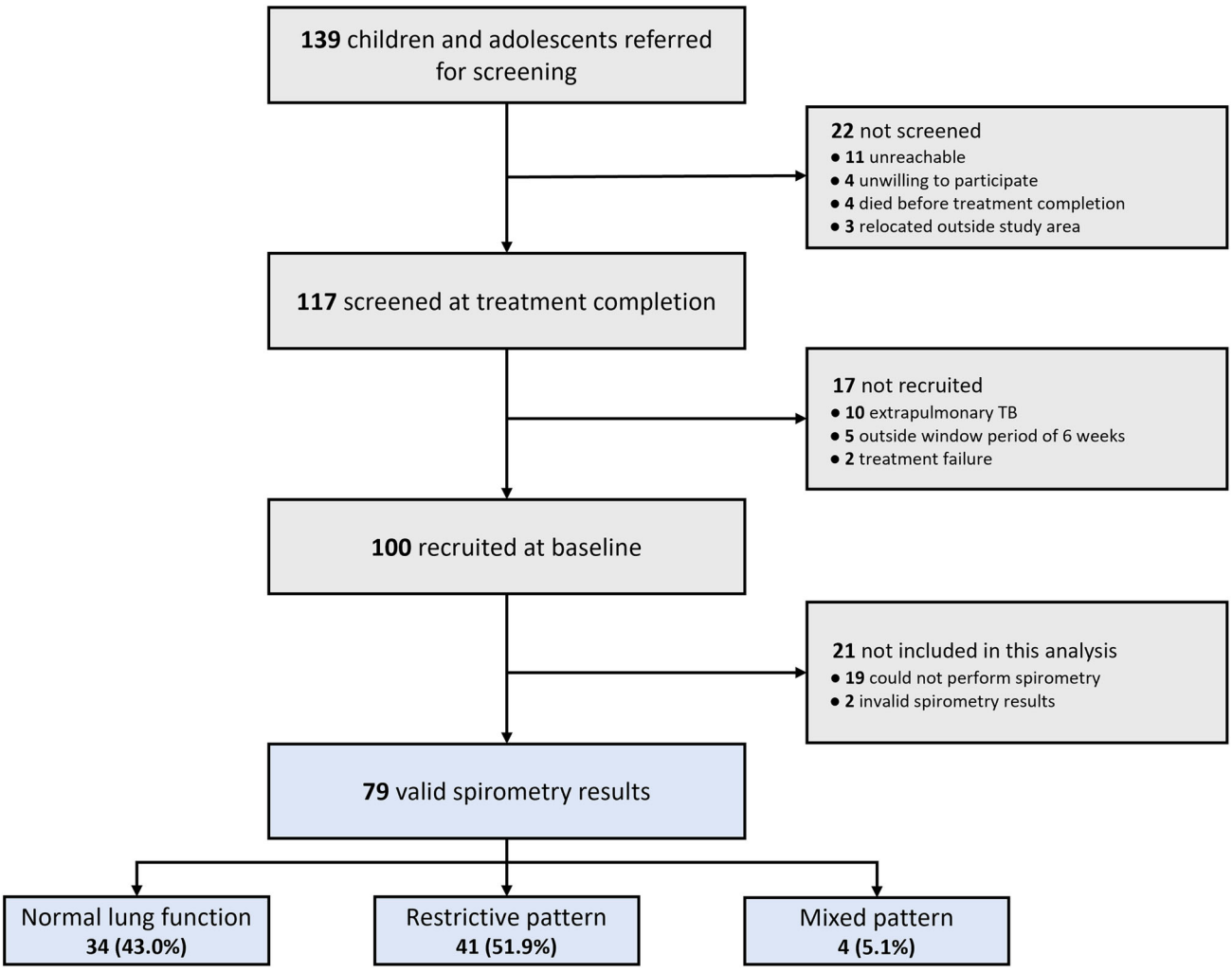


**FIGURE 1** Study flowchart and spirometry outcomes. Obstructive pattern: postbronchodilator (post-BD) $FEV_1$/FVC ratio z-score below the lower limit of normal (LLN); Restrictive pattern: post-BD FVC z-score below LLN; Mixed: post-BD FVC z-score and $FEV_1$/FVC z-score below LLN; LLN = −1.64. The 19 children who could not perform spirometry were all aged below 5 years.

between post-TB respiratory impairment defined by abnormal spirometry and a priori defined pre- and post-TB treatment characteristics. We then fitted a multivariable logistic regression model incorporating variables with $p < .10$ from the univariable model. We reported odds ratios with 95% CI. Data were analysed using Stata/SE V.17.0 statistical software.

### 2.4 | Role of funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation or writing of the report. The corresponding author had full access to all study data and had final responsibility for the decision to submit for publication.

## 3 | RESULTS

A total of 139 children and adolescents were referred from the NLTP clinics to our Childhood TB research clinic during their last month of antituberculous therapy. After completion of treatment, 117 participants were screened, of whom 17 were ineligible for enrollment because they had a previous diagnosis of extrapulmonary TB alone without pTB ($n = 10$), were 6 weeks past the end of treatment ($n = 5$), or had treatment failure ($n = 2$). The study enrolled 100 children and adolescents between March 2022 and July 2023, of whom 79 had valid spirometry results (Figure 1). The characteristics of the participants who were not included in the analysis are shown in Supporting Information S1: Table 1.

### 3.1 | Participant characteristics

The baseline characteristics of the participants are detailed in Table 1. The median age was 15.6 years (IQR: 11.8, 17.9), 41/79 (51.9%) were female, and 8/79 (10.1%) were living with HIV. The median self-reported duration of illness before commencing TB treatment was 4.0 weeks (IQR: 3.0, 5.0). Although most participants (97.5%) had never smoked, the majority (74.7%) reported exposure to environmental tobacco smoke and cooking with biomass fuels (94.9%).

Except for age, the confirmed and unconfirmed participants had similar demographic characteristics. The confirmed TB group was significantly older, with a median age of 17.0 years (IQR: 13.1, 18.0) compared to 12.3 years (IQR: 8.1, 14.0) in the unconfirmed TB group.

**TABLE 1** Participant characteristics and spirometry result at TB treatment completion stratified by prior tuberculosis diagnosis.

| | Total ($n = 79$) | Unconfirmed TB ($n = 26$) | Confirmed TB ($n = 53$) |
|---|---|---|---|
| Age, years | 15.6 (11.8, 17.9) | 12.3 (8.1, 14.0) | 17.0 (13.1, 18.0) |
| Female | 41 (51.9) | 11 (42.3) | 30 (56.6) |
| HIV infection | 8 (10.1) | 5 (19.2) | 3 (5.6) |
| Asthma | 1 (1.3) | 1 (3.9) | 0 |
| Sickle Cell Anemia | 3 (3.8) | 3 (11.5) | 0 |
| Ever smoked | 2 (2.5) | 1 (3.9) | 1 (1.9) |
| Exposure to environmental tobacco smoke | 59 (74.7) | 18 (69.2) | 41 (77.4) |
| Household biomass exposure | 75 (94.9) | 25 (96.2) | 50 (94.3) |
| More than one previous TB | 2 (2.5) | 1 (3.9) | 1 (1.9) |
| Self-reported duration of TB illness before treatment, weeks | 4.0 (3.0, 5.0) | 4.0 (3.0, 5.0) | 4.0 (3.0, 5.0) |
| Time since TB treatment completion, weeks | 1.2 (0.8, 2.4) | 1.2 (0.4, 2.4) | 1.2 (0.8, 2.4) |
| **Spirometry** | | | |
| $FEV_1$ z-score | −1.51 (−2.82, −0.96) | −1.55 (−3.29, −0.63) | −1.51 (−2.55, −1.11) |
| FVC z-score | −1.84 (−2.92, −1.07) | −1.59 (−3.66, −0.83) | −1.87 (−2.58, −1.29) |
| $FEV_1$/FVC z-score | 0.20 (−0.68, 0.79) | 0.02 (−1.12, 0.61) | 0.29 (−0.51, 0.84) |
| Abnormal spirometry | 45 (57.0) | 13 (50.0) | 32 (60.4) |
| **Pattern of spirometry** | | | |
| Normal | 34 (43.0) | 13 (50.0) | 21 (39.6) |
| Restrictive | 41 (51.9) | 11 (42.3) | 30 (56.6) |
| Mixed | 4 (5.1) | 2 (7.7) | 2 (3.8) |

*Note*: Data are *n* (%) or median (IQR).

### 3.2 | Lung function impairment at TB treatment completion

The median $FEV_1$ and FVC z-scores were −1.51 (IQR: −2.82, −0.96) and −1.84 (−2.92, −1.07), respectively. Forty-five participants (57.0%) had abnormal spirometry; the most common type of abnormality was the restrictive pattern seen in 41/79 (51.9%), followed by the mixed pattern in 4/79 (5.1%) (Table 1). Using the GLI race-neutral reference equations resulted in significantly lower median $FEV_1$ and FVC z-scores compared to the African American reference equations, resulting in 15 additional participants having abnormal spirometry (Table 2, Supplementary Material). The clinical characteristics and CXR results of the 15 participants whose spirometry was 'normal' with the African American and 'abnormal' with the race-neutral equations, respectively, are shown in Table 3 of the Supplementary Material.

### 3.3 | Clinical and respiratory parameters at TB treatment completion

Twenty-eight (35.4%) of the participants reported one or more chronic or recurrent respiratory symptom(s) present at the completion of TB treatment (Table 2). The most common symptom was cough in 21/79 participants (26.6%), followed by sputum production in 14/79 participants (17.2%). Participants experienced similar respiratory symptoms irrespective of their spirometry results.

At treatment completion, 8/79 (10.1%) participants were stunted, while 21/79 (26.6%) were underweight. More participants in the abnormal spirometry group were underweight, with a median BMI-for-age z-score of −1.65 (−2.41, −0.91) compared to −0.68 (−1.40, −0.30) in the normal spirometry group, $p < .001$.

**TABLE 2** Clinical and respiratory parameters measured at TB treatment completion stratified by spirometry outcome.

| | Total ($n = 79$) | Normal spirometry ($n = 34$) | Abnormal spirometry ($n = 45$) | $p$ value |
|---|---|---|---|---|
| Confirmed TB | 53 (67.1) | 21 (61.8) | 32 (71.1) | .470 |
| **Self-reported symptoms*** | | | | |
| Any respiratory symptom | 28 (35.4) | 9 (26.5) | 19 (42.2) | .163 |
| Cough | 21 (26.6) | 7 (20.6) | 14 (31.1) | .318 |
| Sputum | 14 (17.2) | 4 (11.8) | 10 (22.2) | .373 |
| Shortness of breath | 9 (11.4) | 4 (11.8) | 5 (11.1) | .999 |
| Wheeze | 5 (6.3) | 1 (2.9) | 4 (8.9) | .384 |
| **Clinical observations** | | | | |
| Height-for-age z-score | −0.74 (−1.40, −0.06) | −0.76 (−1.34, −0.37) | −0.65 (−1.56, 0.43) | .593 |
| BMI-for-age z-score | −1.25 (−2.06, −0.47) | −0.68 (−1.40, −0.30) | −1.65 (−2.41, −0.91) | <.001 |
| Stunted | 8 (10.1) | 2 (5.9) | 6 (13.3) | .455 |
| Underweight | 21 (26.6) | 4 (11.8) | 17 (37.8) | .011 |
| Oxygen saturations, % | 99 (99, 100) | 99 (99, 100) | 99 (99, 100) | .741 |
| **Chest X-ray findings, $n = 78$** | | | | |
| Abnormal chest X-ray | 37 (47.4) | 9 (26.5) | 28 (63.6) | .001 |
| Pattern of abnormality | | | | |
| Fibrosis | 22 (28.2) | 5 (14.7) | 17 (38.6) | .024 |
| Volume loss | 7 (9.0) | 0 | 7 (15.9) | .017 |
| Bronchiectasis | 6 (7.7) | 0 | 6 (13.6) | .033 |
| Parenchymal infiltrates | 4 (5.1) | 1 (2.9) | 3 (6.8) | .628 |
| Cavity | 3 (3.9) | 0 | 3 (6.8) | .253 |
| Consolidation | 2 (2.6) | 0 | 2 (4.6) | .502 |
| Pleural effusion | 2 (2.6) | 0 | 2 (4.6) | .502 |
| Collapse | 1 (1.3) | 0 | 1 (2.3) | .999 |

*Note*: Data are *n* (%) or median (IQR).

*Symptoms present if the self-reported frequency is at least a few days per month.

**TABLE 3** Factors associated with abnormal lung function at TB treatment completion among participants who performed spirometry.

| | Univariable analysis | | Multivariable analysis | |
|---|---|---|---|---|
| | OR (95% CI) | *p* value | aOR (95% CI) | *p* value |
| **Pre-TB characteristics** | | | | |
| Age at TB diagnosis >10 years | 3.1 (1.0, 9.5) | .047 | 4.3 (1.0, 18.4) | .050 |
| Male | 0.9 (0.4, 2.1) | .769 | - | - |
| HIV positive | 0.9 (0.8, 1.1) | .462 | - | - |
| Exposed to environmental tobacco smoke | 0.6 (0.2, 1.8) | .403 | - | - |
| Exposed to household biomass | 1.3 (0.2, 10.1) | .774 | - | - |
| Confirmed TB diagnosis | 1.5 (0.6, 3.9) | .383 | - | - |
| Self-reported duration of TB illness before treatment >4 weeks | 1.5 (0.6, 3.8) | .439 | - | - |
| Time since TB treatment completion >4 weeks | 1.3 (0.3, 5.8) | .739 | - | - |
| **Posttreatment characteristics** | | | | |
| Self-reported symptoms | | | | |
| Cough | 1.7 (0.6, 4.9) | .297 | - | - |
| Sputum production | 2.1 (0.6, 7.5) | .235 | - | - |
| Shortness of breath | 0.9 (2.3, 3.8) | .928 | - | - |
| Wheeze | 3.2 (0.3, 30.2) | .306 | - | - |
| Clinical observations | | | | |
| Stunted | 2.4 (0.5, 13.0) | .290 | - | - |
| Underweight | 4.6 (1.4, 15.2) | .014 | 8.3 (2.0, 35.2) | .004 |
| Chest X-ray findings | | | | |
| Fibrosis | 3.7 (1.2, 11.3) | .024 | 3.6 (1.1, 12.0) | .038 |
| Parenchymal infiltrates | 2.4 (0.2, 24.3) | .454 | | |

Of the 78/79 (98.7%) participants who had CXRs available, 37/78 (47.4%) had abnormal CXRs at treatment completion. There was a good inter-reader agreement for the presence of radiological sequelae (kappa: 0.62), with only 18 CXRs requiring a third reader. The most common abnormality was fibrosis, seen in 22/78 (28.2%), followed by volume loss seen in 7/78 (9.0%) and bronchiectasis in 6/78 (7.7%), Figure 2. The frequency of radiological sequelae was significantly higher in the abnormal spirometry group (28/45, 63.6%) compared to the normal group (9/34, 26.5%), $p = .001$.

## 3.4 | Factors associated with lung function impairment

Following the univariable logistic regression, age at pTB diagnosis, posttreatment weight status, and presence of fibrosis on CXR at the end of treatment showed a $p < .10$ and were subsequently included in the multivariable analysis. Multivariable logistic regression was then performed and showed that age older than ten years at pTB diagnosis, being underweight, and having fibrosis on CXR at treatment completion were strongly associated with abnormal post-TB spirometry ($p = .050$, .004, and .038, respectively). There was no significant relationship between any self-reported symptom and abnormal spirometry at TB treatment completion (Table 3).

## 3.5 | Correlation of respiratory symptoms, radiological sequelae and lung function impairment at TB treatment completion

Figure 3 shows the subsets of presentations of respiratory impairment, which characterized the 78 participants who had symptom screening, spirometry, and CXR done. The single most common respiratory impairment was an abnormal spirometry seen in 44/78 (56.4%) participants. The largest combination of respiratory impairments was abnormal spirometry and CXR (17/78, 22%), while the least common subset was participants with respiratory symptoms and abnormal CXRs (1/78, 1%).

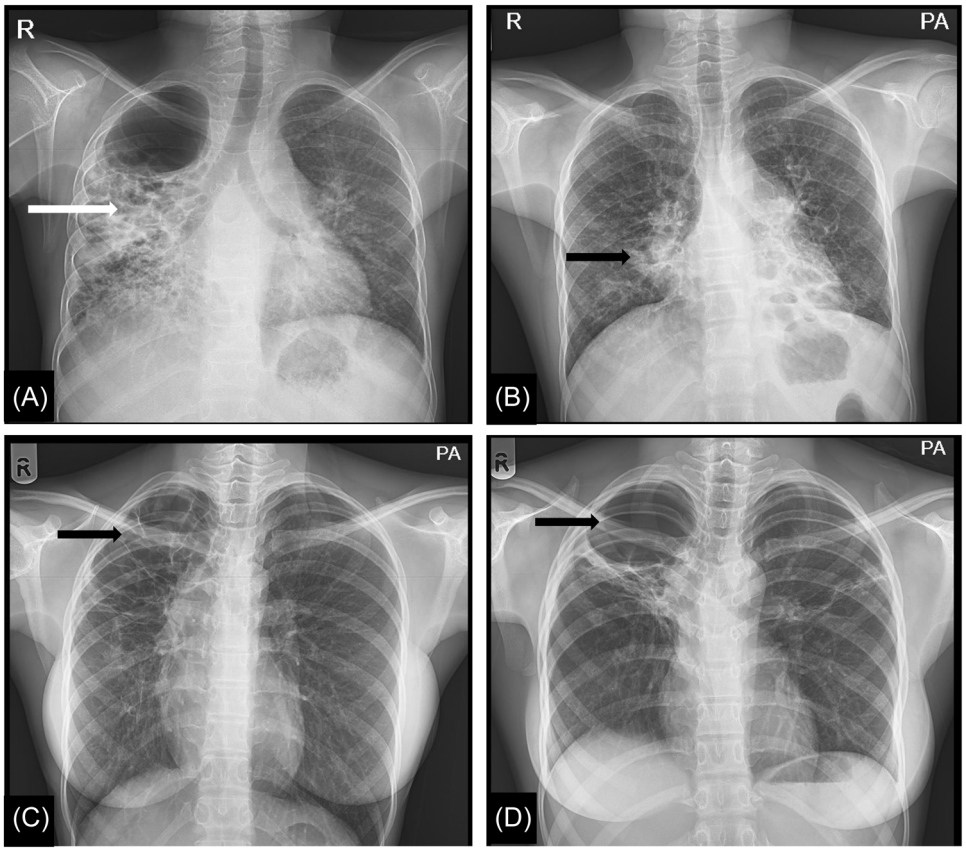


**FIGURE 2** Chest X-ray imaging from participants with severe radiological abnormalities. (A) Bronchiectasis (arrow) with volume loss on the right. (B) Fibrosis (arrow). (C) Fibrosis with bronchiectasis (arrow) in the right upper zone. (D) Fibrosis with volume loss and cavitation (arrow) in the right upper zone.

## 4 | DISCUSSION

Our findings indicate that more than half of children and adolescents have impaired spirometry at TB treatment completion. Additionally, several of these TB survivors have abnormal CXR and continue to experience respiratory symptoms at this stage. Furthermore, age above 10 years at pTB diagnosis, undernutrition and fibrosis on CXR at treatment completion were strongly associated with impaired spirometry after TB. Notably, the majority of children and adolescents with respiratory abnormalities had either an abnormal CXR or abnormal spirometry.

Our study provides compelling evidence of the respiratory consequences of childhood and adolescent TB, building upon previous research in the same geographical area.[11] Moreso, the high proportion of children with abnormal spirometry in our study corroborates recently published data from South Africa, which found that up to 65% of adolescent TB survivors had abnormal spirometry at treatment completion. These studies indicate that TB has a detrimental effect on the lung function of young individuals, which is still present at treatment completion. We aim to track the longitudinal changes in spirometry within this cohort over time to assess its evolution.

The most frequently observed symptom in this cohort was chronic or recurrent cough, which is similar to what is commonly reported in the literature.[6,9,11,13,23] Similar to previous published post-TB studies in adults and children, we also found fibrosis to be the most common radiological sequelae and restrictive spirometry pattern as the most common lung function abnormality.[6,11,14,23] However, despite CXR and spirometry identifying more than two-thirds of all children with respiratory sequelae, there was minimal overlap between symptoms, CXR appearance and abnormal lung function. This finding is unsurprising since persistent post-TB symptoms correlate poorly with lung function.[24] The wide range of phenotypes observed in our study emphasizes the need for comprehensive post-TB assessments in children and adolescents.

The association between a low BMI at TB treatment completion and impaired lung function, as seen in our study, has been previously reported.[9] Low BMI is known to predict lung function decline in adults.[25] As proper nutrition is vital for supporting lung health, we expect the effects of undernutrition to be even more pronounced in children. This finding underscores the significance of addressing malnutrition during TB treatment, which we hope will improve lung health and treatment outcomes.[26]

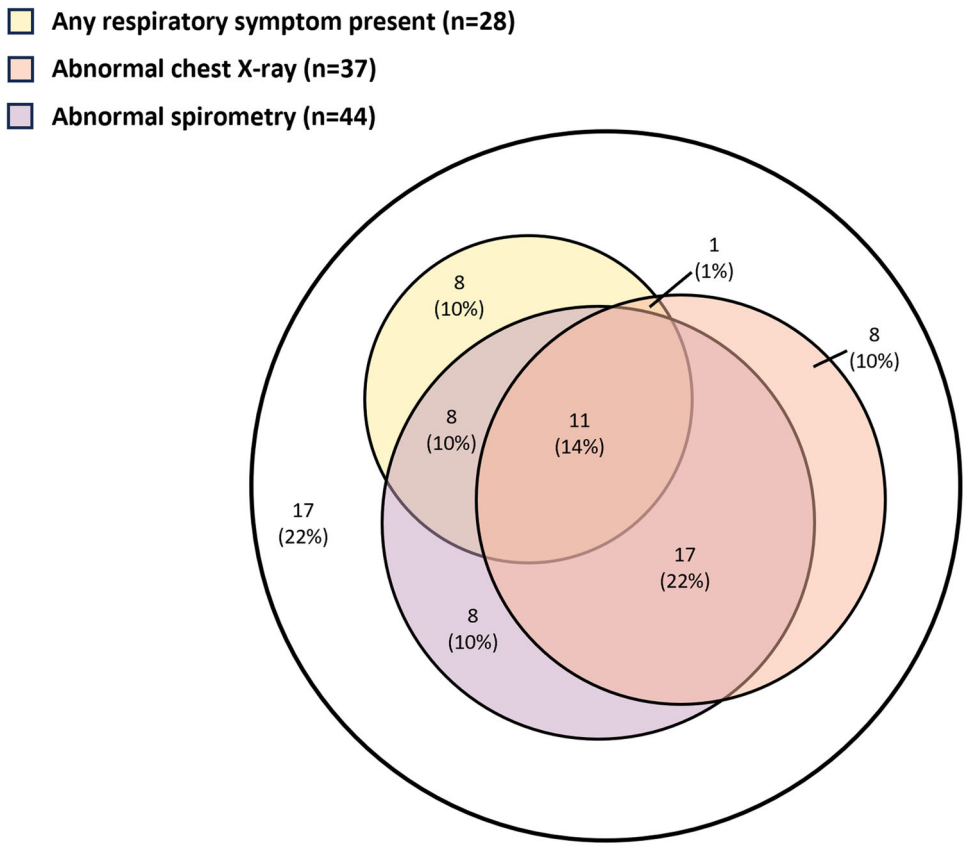


**FIGURE 3** Relationship between the outcomes at treatment completion among 78 participants aged 5 years and older using symptom screening, spirometry, and chest X-ray.

Defining pediatric PTLD and assessing its severity presents several challenges.[2] First, relying on self- or parent-reported symptoms may be subject to recall bias.[27] Second, the interpretation of CXR can exhibit variability between clinicians.[28,29] Third, the disease characteristics differ with age, with adolescents often displaying a disease pattern more akin to adults.[30] The diversity in the presentation of childhood and adolescent TB implies that the definition of PTLD may also vary across the pediatric age spectrum. Given these challenges, incorporating an objective assessment such as lung function measurement using spirometry alongside other metrics can enhance diagnostic precision. Nonetheless, due to limited accessibility to spirometry, alternative proxies such as posttreatment anthropometric measurements and CXR findings become valuable tools for evaluating lung function in the post-TB pediatric population. Furthermore, since CXRs cannot reliably differentiate the radiological patterns of PTLD, more elaborate radiological imaging, such as CT scans, should be considered where indicated and available.[31]

A notable strength of our study is being one of the first to document post-TB characteristics in children and adolescents. Additionally, including older adolescents further strengthens the study, as this age group is often excluded from both childhood and adult TB studies. However, the lack of pre-TB anthropometry measurements and CXR data represents a study limitation, hindering our ability to directly compare and fully assess the impact of nutritional status and radiological severity of pTB on post-TB lung health. The absence of a comparison group may also be considered a limitation, especially considering that our previous study reported a substantial burden of chronic respiratory symptoms and impaired lung function among children and adolescents without TB.[11] Moreover, it is important to acknowledge that it might be too early to fully capture post-TB effects within 6 weeks of TB treatment completion. For these reasons, we are conducting a longitudinal follow-up of this cohort to observe how these characteristics evolve over time.

In conclusion, we found that a high proportion of childhood and adolescent TB survivors continue to have any or all of chronic respiratory symptoms, abnormal CXR, or impaired lung function after completing treatment. These findings underscore the necessity for ongoing monitoring to improve the health and well-being of children and adolescents who have been treated for TB. In the absence of spirometry, we recommend symptom screening, anthropometry, and CXR as a minimum. Additionally, nutritional support during treatment may improve post-TB respiratory outcomes in children and adolescents.

## AUTHOR CONTRIBUTIONS

**Esin Nkereuwem**: Conceptualization; investigation; funding acquisition; writing—original draft; methodology; writing—review and

editing; formal analysis; data curation; project administration; supervision. **Schadrac Agbla**: Formal analysis; writing—review and editing. **Bintou Njai**: Data curation; writing—review and editing. **Victory Fabian Edem**: Writing—review and editing. **Muhammed Lamin Jatta**: Data curation; writing—review and editing. **Olumuyiwa Owolabi**: Writing—review and editing; project administration; data curation. **Uma Masterton**: Writing—review and editing; project administration; data curation. **Fatoumatta Jah**: Writing—review and editing; project administration; data curation. **Madikoi Danso**: Writing—review and editing; project administration; data curation. **Aunty Nyima Fofana**: Writing—review and editing; project administration; data curation. **Wandifa Samateh**: Writing—review and editing. **Muhammed Lamin Darboe**: Writing—review and editing. **Sheila Ageiwaa Owusu**: Writing—review and editing. **Andrew Bush**: Writing—review and editing. **Beate Kampmann**: Conceptualization; funding acquisition; writing—original draft; methodology; supervision; writing—review and editing. **Toyin Togun**: Conceptualization; funding acquisition; writing—original draft; methodology; writing—review and editing; supervision.

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## CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

## DATA AVAILABILITY STATEMENT

Data are available upon reasonable request.

## ETHICS STATEMENT

This study involved human participants and was approved by The Gambia Government/MRC Joint Ethics Committee (Ethics Ref: 22,613) and the Observational/Interventions Research Ethics Committee of the London School of Hygiene and Tropical Medicine (Ethics Ref: 22,613–2). Participants gave informed consent to participate in the study before taking part.

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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