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Original Article

Risk Factors for Tuberculosis in Children

Dr. Komal[1], Dr. Shamayal Mandokhel[1], Dr. Umme Habiba[1], Dr. Maria Sherani[1], Dr. Sana Baloch[1], Dr. Aqsa Mehmood[1]

[1] Department of Paediatrics, Balochistan Institute of Child Health Service BICHQ, Quetta, Pakistan

*Corresponding author: Dr. Komal, komalbaloch19977@gmail.com

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ABSTRACT

Background: Childhood tuberculosis remains a major contributor to morbidity and mortality in high-burden countries and is frequently under-diagnosed, particularly in resource-limited settings where environmental, household, and nutritional vulnerabilities coexist. Objective: To determine the household and environmental risk factors associated with pulmonary tuberculosis among children aged 1 to 15 years presenting to a tertiary care pediatric hospital in Quetta, Pakistan. Methods: A hospital-based case–control study was conducted at the Institute of Child Health Services, Quetta. Forty-seven children with pulmonary tuberculosis and 47 children without tuberculosis were enrolled. Data on sociodemographic characteristics, household conditions, environmental exposures, nutritional status, and contact history were collected using a structured proforma. Univariate and multivariable logistic regression analyses were performed to estimate crude and adjusted odds ratios with 95% confidence intervals. Results: Children with tuberculosis were more likely than controls to report contact with a known tuberculosis case (55.3% vs 25.5%), absence of cross-ventilation (61.7% vs 40.4%), and malnutrition (42.6% vs 21.3%). On multivariable analysis, household contact with a tuberculosis case (aOR 4.20, 95% CI 1.50-11.50), no cross-ventilation (aOR 2.30, 95% CI 1.00-5.40), and malnutrition (aOR 2.70, 95% CI 1.10-6.80) remained independent predictors of pediatric pulmonary tuberculosis. Conclusion: Household tuberculosis exposure, poor ventilation, and malnutrition are the principal independent risk factors for pediatric tuberculosis in Quetta. Strengthening contact tracing, improving household airflow, and integrating nutritional support into tuberculosis control strategies may help reduce childhood disease burden in high-risk settings. Keywords: pediatric tuberculosis; risk factors; case-control study; malnutrition; ventilation; Quetta; Pakistan.

INTRODUCTION

Tuberculosis remains one of the leading infectious causes of illness and death worldwide, and children continue to bear a substantial but frequently under-recognized share of this burden. Recent global estimates indicate that hundreds of thousands of new tuberculosis cases and tens of thousands of tuberculosis-related deaths occur annually among children younger than 15 years, with the greatest impact observed in low-resource settings and in younger age groups, particularly those under 5 years of age (1). Despite improvements in tuberculosis control in some regions, pediatric tuberculosis remains difficult to diagnose because symptoms are often non-specific, microbiological confirmation is challenging, and surveillance systems tend to under-detect disease in children (2).

Pakistan is among the highest tuberculosis-burden countries globally and contributes a considerable proportion of the world's cases. National estimates suggest a high incidence of tuberculosis, while children account for a meaningful fraction of the total caseload, reflecting ongoing transmission within households and communities (2). This burden is especially concerning in underserved provinces such as Balochistan, where delayed diagnosis, limited access to health services, poverty, and poor living conditions may amplify pediatric vulnerability. Children are biologically more susceptible to progression from infection to active disease because of immature immune responses, and they are also at increased risk of severe manifestations, including disseminated tuberculosis and tuberculous meningitis, both of which are associated with high mortality and long-term disability (3).

The epidemiology of pediatric tuberculosis is strongly shaped by household, environmental, and nutritional determinants. Close contact with an infectious tuberculosis case is consistently identified as the most important exposure, while overcrowded housing, inadequate ventilation, biomass fuel exposure, second-hand tobacco smoke, poor household conditions, and malnutrition further increase the likelihood of infection and disease progression (4,5). A recent systematic review and meta-analysis demonstrated that household contact with a known tuberculosis case increased the odds of pediatric tuberculosis more than six-fold, while indoor smoke exposure, overcrowding, and poor household conditions were also significantly associated with disease risk (5). These findings indicate that pediatric tuberculosis is not only a biomedical problem but also a disease deeply influenced by social and environmental determinants.

Malnutrition is particularly relevant in Pakistan, where child undernutrition remains highly prevalent and may interact synergistically with tuberculosis risk. National nutritional data have shown substantial proportions of underweight, stunted, and wasted children, all of which may compromise immune competence and increase susceptibility to infection (6). Evidence from Pakistani settings has further suggested that malnourished children are disproportionately affected by tuberculosis, supporting a bidirectional relationship in which undernutrition increases disease risk and tuberculosis worsens nutritional status (7). In addition, housing-related exposures such as poor ventilation and indoor smoke may be especially important in crowded urban and peri-urban environments, where prolonged close contact and poor air exchange facilitate airborne transmission (5,8).

Quetta presents a particularly important setting in which to study these determinants because multiple risk factors frequently coexist, including poverty, overcrowded housing, poor ventilation, smoke exposure, and childhood malnutrition. However, despite the high tuberculosis burden and the plausibility of these overlapping exposures, locally grounded evidence quantifying their relative contribution among children in Quetta remains limited. Most available evidence has come either from broader national reports or from studies conducted in other provinces, which may not adequately reflect the social, environmental, and healthcare realities of Balochistan. Defining context-specific determinants is essential for designing targeted interventions such as household contact screening, preventive therapy for exposed children, nutritional support, and environmental risk reduction. Therefore, this study aimed to determine the household and environmental risk factors associated with pulmonary tuberculosis among children aged 1 to 15 years presenting to a tertiary care pediatric hospital in Quetta, Pakistan.

MATERIALS AND METHODS

This hospital-based case–control study was conducted at the Institute of Child Health Services, Quetta, Balochistan, Pakistan, a tertiary pediatric referral center serving both urban and rural populations. Participant recruitment was undertaken over a six-month period from January to June and included children presenting to outpatient and inpatient pediatric services. The case–control design was selected because it is appropriate for evaluating multiple exposures associated with a comparatively uncommon outcome and allows efficient examination of environmental, household, and nutritional determinants of pediatric pulmonary tuberculosis in a resource-constrained clinical setting (9,10).

The study population comprised children aged 1 to 15 years who attended the study site during the recruitment period. Cases were defined as children diagnosed with pulmonary tuberculosis on the basis of compatible clinical features, including persistent cough, weight loss or failure to thrive, fever, night sweats, or lethargy, together with either microbiological confirmation from sputum, gastric aspirate, or other relevant body fluid by culture or GeneXpert, or radiological findings considered consistent with pulmonary tuberculosis and supported by physician judgment (11). Controls were children without tuberculosis recruited from the same hospital during the same study period from services managing non-tuberculosis conditions, including minor injuries and acute illnesses not related to chronic respiratory disease. To improve comparability and reduce confounding by age, controls were frequency-matched to cases by predefined age strata of 1–4 years, 5–9 years, and 10–15 years. Children with congenital lung disease, congenital heart disease, known major immunosuppressive conditions, or chronic illnesses likely to confound the diagnosis or exposure assessment were excluded.

Sample size was determined for an unmatched case–control comparison using expected differences in the prevalence of absence of cross-ventilation between cases and controls, a 95% confidence level, and 80% statistical power, yielding a minimum required sample of 94 participants, comprising 47 cases and 47 controls. Consecutive eligible cases were enrolled during the study period, and controls were selected from the same clinical environment using the same eligibility framework except for disease status. Recruiting cases and controls from the same institution and time window was intended to reduce differential referral and seasonal selection effects, while the use of age-stratified frequency matching helped limit imbalance in one of the most important clinical determinants of pediatric tuberculosis risk.

Data were collected from caregivers using a structured proforma administered by trained research staff. Information captured included sociodemographic characteristics, household conditions, environmental exposures, nutritional indicators, and history of contact with a known tuberculosis case. Sociodemographic variables included age, sex, residence, parental education, and household income. Environmental and household variables included ventilation status, household crowding, cooking fuel exposure, household smoking exposure, source of drinking water, and ingestion of unpasteurized milk. Nutritional assessment was based on anthropometric measurement using standardized techniques. Weight was measured using a calibrated digital scale, height with a stadiometer, and mid-upper arm circumference using standard measuring tape. For children younger than five years, malnutrition was defined as a mid-upper arm circumference below 11.5 cm, whereas for children older than five years, malnutrition was defined as a body mass index below 18.5 kg/m^2. Exposure to a tuberculosis contact was defined as a reported history of contact with a known tuberculosis case in the household or close family environment, with additional details recorded where available regarding the relationship to the index case and treatment status.

Operational definitions were standardized before analysis to improve consistency and reproducibility. Absence of cross-ventilation was defined as the lack of two openings on opposite walls allowing effective airflow through the dwelling. Overcrowding was defined as more than three persons per room. Household smoke exposure was defined as exposure to biomass cooking fuels and/or indoor tobacco smoke. Low parental education was defined as no formal schooling or incomplete primary education, and low household income was defined as a monthly income below PKR 25,000. These definitions were prespecified to minimize classification variability across respondents and data collectors (11,12).

Several measures were used to reduce bias and strengthen internal validity. Cases and controls were recruited from the same hospital over the same period to reduce selection bias. Standardized data collection forms and trained data collectors were used to reduce interviewer variability. Exposure definitions were specified a priori, and anthropometric measurements were obtained using uniform procedures to reduce measurement error. Because caregiver-reported household exposures may be affected by recall limitations, the questionnaire focused on concrete and observable conditions such as room occupancy, smoking exposure, ventilation pattern, and known tuberculosis contact. Potential confounding was addressed analytically by including clinically relevant variables in the multivariable model irrespective of their univariate significance, particularly age, sex, residence, contact history, nutritional status, ventilation status, and overcrowding.

Data were entered and analyzed using SPSS version 26 (IBM Corp., Armonk, NY, USA). Continuous variables were summarized using means with standard deviations or medians with interquartile ranges, as appropriate, while categorical variables were presented as frequencies and percentages. Univariate logistic regression was initially performed to examine the association between each exposure and tuberculosis status, and crude odds ratios with 95% confidence intervals were estimated. Variables showing a univariate association at $p<0.25$, together with variables considered clinically important on epidemiological grounds, were entered into the multivariable logistic regression model. Adjusted odds ratios with 95% confidence intervals were then calculated to identify independent predictors of pediatric pulmonary tuberculosis. Interaction terms were examined to assess possible effect modification by age, residence, and income, and stratified analyses were explored where relevant. Collinearity among predictors was assessed using variance inflation factors, and the adequacy of model fit was evaluated using the Hosmer–Lemeshow goodness-of-fit test. Data completeness was checked before analysis, and records with missing values in model variables were handled using complete-case analysis. Statistical significance was defined at $p<0.05$.

Written informed consent was obtained from parents or legal guardians before enrollment, and assent was obtained from children older than seven years where appropriate. Participant confidentiality was maintained through anonymized coding and restricted access to the dataset. Study procedures were conducted in accordance with established ethical principles for human research and with reporting expectations for observational studies (9,10).

RESULTS

A total of 94 children were included in the analysis, comprising 47 cases with pulmonary tuberculosis and 47 controls without tuberculosis. The mean age of the overall sample was 6.8 ± 3.9 years. Children aged 1–4 years constituted the largest age stratum among cases (44.7%) compared with controls (29.8%), whereas the proportions in the 5–9 year and 10–15 year categories were broadly comparable between groups. Sex distribution was similar, with males accounting for 55.3% of cases and 53.2% of controls (p=0.84). Residence also did not differ significantly, as 59.6% of cases and 61.7% of controls were from urban settings (p=0.83), suggesting reasonable baseline comparability between the two groups on the principal demographic characteristics assessed.

Table 1. Baseline Characteristics of Study Participants (N=94)

Characteristic	Cases (n=47)	Controls (n=47)	Total (N=94)	p-value
Age group				0.18
1–4 years	21 (44.7%)	14 (29.8%)	35 (37.2%)	
5–9 years	16 (34.0%)	19 (40.4%)	35 (37.2%)	
10–15 years	10 (21.3%)	14 (29.8%)	24 (25.5%)	
Sex				0.84
Male	26 (55.3%)	25 (53.2%)	51 (54.3%)	
Female	21 (44.7%)	22 (46.8%)	43 (45.7%)	
Residence				0.83
Urban	28 (59.6%)	29 (61.7%)	57 (60.6%)	
Rural	19 (40.4%)	18 (38.3%)	37 (39.4%)	

Household and environmental exposures were more frequent among children with tuberculosis than among controls across most variables studied. Contact with a known tuberculosis case was reported in 55.3% of cases compared with 25.5% of controls, representing the largest absolute exposure gap between groups. Absence of cross-ventilation was present in 61.7% of cases versus 40.4% of controls, while malnutrition affected 42.6% of cases compared with 21.3% of controls. Overcrowding and household smoke exposure each occurred in 44.7% of cases and 27.7% of controls. Lower between-group differences were observed for unpasteurized milk consumption (19.1% vs 10.6%), low maternal education (48.9% vs 38.3%), and low household income (57.4% vs 51.1%). These descriptive differences suggested a consistent trend toward greater household vulnerability among affected children, particularly in relation to direct exposure, ventilation, and nutritional status.

Table 2. Prevalence of Household and Environmental Exposures Among Cases and Controls

Exposure	Cases (n=47)	Controls (n=47)	Total (N=94)	Absolute Difference (percentage points)
Contact with TB case	26 (55.3%)	12 (25.5%)	38 (40.4%)	29.8
No cross-ventilation	29 (61.7%)	19 (40.4%)	48 (51.1%)	21.3
Overcrowding	21 (44.7%)	13 (27.7%)	34 (36.2%)	17.0
Household smoke exposure	21 (44.7%)	13 (27.7%)	34 (36.2%)	17.0
Malnutrition	20 (42.6%)	10 (21.3%)	30 (31.9%)	21.3
Unpasteurized milk use	9 (19.1%)	5 (10.6%)	14 (14.9%)	8.5
Low maternal education	23 (48.9%)	18 (38.3%)	41 (43.6%)	10.6
Low household income	27 (57.4%)	24 (51.1%)	51 (54.3%)	6.3

On univariate logistic regression, three variables met conventional statistical significance thresholds. Children with a history of household contact with a tuberculosis case had 3.90 times the odds of pulmonary tuberculosis compared with unexposed children (95% CI: 1.50–10.20; p=0.004). Absence of cross-ventilation was associated with a 2.30-fold increase in odds (95% CI: 1.00–5.30; p=0.047), while malnutrition was associated with a 2.90-fold increase (95% CI: 1.10–7.60; p=0.028). Overcrowding and household smoke exposure both showed elevated crude odds ratios of 2.07, but these did not reach statistical significance (p=0.108 for each). Unpasteurized milk consumption, low maternal education, and low household income were also positively associated with tuberculosis in direction, but their confidence intervals crossed unity and the corresponding p-values did not support statistical significance.

Table 3. Univariate Logistic Regression for Risk Factors of Pediatric Tuberculosis

Variable	OR	95% CI	p-value
Contact with TB case	3.90	1.50–10.20	0.004
No cross-ventilation	2.30	1.00–5.30	0.047
Malnutrition	2.90	1.10–7.60	0.028
Overcrowding	2.07	0.85–5.06	0.108
Household smoke exposure	2.07	0.85–5.06	0.108
Unpasteurized milk use	1.95	0.57–6.66	0.280
Low maternal education	1.53	0.67–3.47	0.311
Low household income	1.27	0.57–2.81	0.553

After multivariable adjustment for age, sex, residence, and the selected household and environmental variables, three exposures remained independently associated with pediatric pulmonary tuberculosis. Contact with a known tuberculosis case remained the strongest predictor, with an adjusted odds ratio of 4.20 (95% CI: 1.50–11.50; p=0.006), indicating that exposed children had more than fourfold higher odds of disease after accounting for covariates. Absence of cross-ventilation also retained statistical significance, with an adjusted odds ratio of 2.30 (95% CI: 1.00–5.40; p=0.049), suggesting approximately doubled odds of tuberculosis in poorly ventilated dwellings. Malnutrition remained independently significant as well, with an adjusted odds ratio of 2.70 (95% CI: 1.10–6.80; p=0.031). In contrast, overcrowding, household smoke exposure, unpasteurized milk intake, low maternal education, and low household income all showed adjusted odds ratios above 1.0 but were no longer statistically significant, implying either weaker independent effects or limited power to confirm those associations within this sample.

Table 4. Multivariable Logistic Regression for Independent Predictors of Pediatric Tuberculosis

Variable	aOR	95% CI	p-value	Interpretation
Contact with TB case	4.20	1.50–11.50	0.006	Strong independent predictor
No cross-ventilation	2.30	1.00–5.40	0.049	Independent predictor
Malnutrition	2.70	1.10–6.80	0.031	Independent predictor
Overcrowding	1.80	0.70–4.70	0.220	Not statistically significant
Household smoke exposure	1.90	0.80–4.80	0.160	Not statistically significant
Unpasteurized milk use	1.50	0.40–5.40	0.520	Not statistically significant
Low maternal education	1.40	0.60–3.40	0.410	Not statistically significant
Low household income	1.20	0.50–2.80	0.670	Not statistically significant

Overall, the quantitative pattern across descriptive and inferential analyses was highly coherent. The three variables that showed the greatest exposure gradients between groups, namely tuberculosis contact, lack of cross-ventilation, and malnutrition, were also the only factors that remained independently significant after adjustment. Contact history produced both the largest absolute prevalence gap between cases and controls (29.8 percentage points) and the largest adjusted effect estimate (aOR 4.20). Ventilation status and malnutrition each showed a 21.3 percentage-point difference between groups and retained adjusted odds ratios above 2.0, reinforcing their likely clinical and public health relevance. By contrast, variables such as low income and low maternal education appeared common in both groups, which may explain their smaller between-group contrasts and weaker regression signals in this dataset.

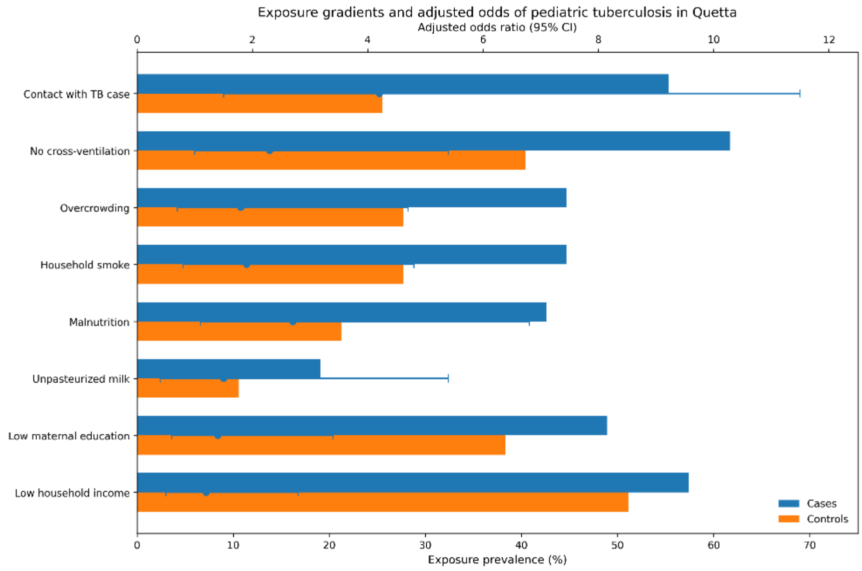

Figure 1 Exposure gradients and adjusted odds of pediatric tuberculosis in Quetta

Exposure gradients and adjusted odds of pediatric tuberculosis in Quetta. The figure integrates exposure prevalence in cases and controls with adjusted odds ratios and 95% confidence intervals. The widest prevalence separation was observed for household tuberculosis contact, reported in 55.3% of cases versus 25.5% of controls, corresponding to the strongest adjusted association with disease (aOR 4.20, 95% CI: 1.50–11.50). Absence of cross-ventilation showed a similarly notable exposure gradient, affecting 61.7% of cases and 40.4% of controls, with an independent adjusted effect of 2.30 (95% CI: 1.00–5.40). Malnutrition was present in 42.6% of cases compared with 21.3% of controls and remained significantly associated with tuberculosis after adjustment (aOR 2.70, 95% CI: 1.10–6.80). Overcrowding and household smoke exposure displayed moderate prevalence gaps of 17.0 percentage points each, but their adjusted confidence intervals crossed unity, indicating weaker independent evidence in this sample. Together, the pattern suggests that direct infectious exposure, impaired household airflow, and nutritional vulnerability form the most clinically meaningful risk gradient in this pediatric population.

DISCUSSION

This hospital-based case–control study identified three independent predictors of pediatric pulmonary tuberculosis in Quetta: household contact with a known tuberculosis case, absence of cross-ventilation, and malnutrition. Among these, contact history showed the strongest association, with more than fourfold higher adjusted odds of disease, while poor ventilation and malnutrition each remained associated with approximately doubled to nearly tripled odds after multivariable adjustment. These findings are clinically coherent and epidemiologically plausible, as they reflect the combined contribution of infectious exposure, environmental transmission conditions, and host vulnerability in shaping pediatric tuberculosis risk. In a setting such as Quetta, where household crowding, suboptimal housing quality, and nutritional deprivation frequently coexist, the persistence of these three factors in adjusted analysis suggests that they are not merely background correlates of poverty, but likely major proximate determinants of childhood tuberculosis in routine clinical practice (13,14).

The strongest relationship in the present study was observed for household contact with a known tuberculosis case. This finding is consistent with the biological basis of pediatric tuberculosis, as children most commonly acquire infection from infectious adult contacts within the household, where repeated close exposure and prolonged indoor contact facilitate transmission. Once infected, younger children are particularly vulnerable to progression from infection to active disease because of immature immune defenses and difficulties in early recognition. Previous work from Pakistan and other high-burden settings has similarly demonstrated that household exposure is the dominant epidemiological driver of pediatric tuberculosis, and our findings reinforce that this pattern is highly relevant in Balochistan as well. From a programmatic perspective, this result supports the prioritization of active household contact investigation, early screening of exposed children, and provision of appropriate preventive therapy as central components of pediatric tuberculosis control (15,16).

Poor household ventilation also remained independently associated with disease after adjustment. This finding is important because it emphasizes that transmission risk is shaped not only by the presence of an infectious source but also by the physical environment in which exposure occurs. In poorly ventilated dwellings, infectious droplet nuclei may remain suspended for longer periods, increasing the likelihood of inhalation by susceptible children. In communities where extended families share limited indoor space and seasonal or structural conditions restrict airflow, inadequate cross-ventilation may substantially intensify household transmission. The observed association therefore extends beyond a simple housing characteristic and points to a modifiable exposure pathway. Public health interventions that improve indoor airflow, reduce prolonged exposure in enclosed rooms, and integrate ventilation awareness into tuberculosis prevention messaging may offer practical value, particularly in low-resource urban settings where major structural housing changes are difficult to achieve immediately (17,18).

Malnutrition emerged as the third independent predictor and represents an equally important clinical concern. Undernutrition compromises both innate and adaptive immune function, impairs the host response to mycobacterial infection, and may increase both susceptibility to disease and the severity of clinical progression. At the same time, tuberculosis itself worsens nutritional status through reduced appetite, systemic inflammation, and catabolic stress, creating a self-reinforcing cycle between infection and undernutrition. The association observed in this study is therefore consistent with both pathophysiological understanding and previous evidence from South Asian populations. In practical terms, this finding suggests that nutritional assessment should not be viewed as a peripheral issue in pediatric tuberculosis care; rather, it should be integrated into routine risk stratification, treatment support, and community-level prevention efforts. In high-burden environments such as Quetta, linking tuberculosis programs with maternal-child nutrition services may be especially important for reducing both incident disease and adverse outcomes among affected children (19,20).

Although overcrowding and household smoke exposure showed increased crude and adjusted odds ratios, neither remained statistically significant in the final model. These variables have been associated with pediatric tuberculosis in prior studies and remain epidemiologically relevant, but their independent effects may have been attenuated here by overlap with stronger proximal determinants such as contact history and ventilation status, as well as by the limited statistical power of the present sample. Similarly, low maternal education and low household income were common in both groups and did not show significant adjusted associations, which may indicate that their influence operates indirectly through more immediate environmental and nutritional pathways. This pattern is important because it suggests that broad socioeconomic disadvantage remains part of the causal context, even when not retained as an independent variable in the regression model. In other words, poverty may still matter substantially, but its measurable effect in this dataset appears to be mediated through household structure, exposure intensity, and child nutritional status rather than through income alone (21,22).

The present findings have direct implications for tuberculosis control policy and service delivery in Balochistan. First, the strength of the contact-history association supports intensifying household contact tracing and preventive treatment strategies, especially for younger children exposed to adult index cases. Second, the association with ventilation suggests that environmental counseling should be incorporated into pediatric tuberculosis prevention, including practical advice about airflow, smoke reduction, and household risk awareness. Third, the role of malnutrition indicates that pediatric tuberculosis programs should be linked more deliberately with nutritional screening and support, particularly in regions where chronic undernutrition is already widespread. These interventions are attractive because they address identifiable and modifiable determinants rather than relying solely on passive case detection. In a province with persistent structural barriers to healthcare access, targeted household-based prevention may yield better impact than waiting for advanced disease to present at tertiary centers (23,24).

This study has several strengths. It provides locally relevant data from Quetta, a region in which pediatric tuberculosis risk has been understudied despite clear epidemiological vulnerability. The case–control design was appropriate for evaluating multiple exposures, and the use of multivariable analysis improved the ability to distinguish independent predictors from correlated background factors. Recruitment of cases and controls from the same institution during the same period also improved comparability. At the same time, several limitations should be acknowledged. The sample size was modest, which may have reduced power to detect weaker but still clinically important associations. Because the study was hospital-based, the findings may not be fully generalizable to community populations, particularly children with milder or undiagnosed disease. Some exposure data depended on caregiver report and may therefore be subject to recall or reporting bias. In addition, pediatric tuberculosis diagnosis is often challenging and may rely on a combination of clinical, radiological, and laboratory evidence, introducing some potential for diagnostic misclassification despite efforts at standardized case definition. These limitations do not negate the findings, but they do suggest that larger community-based studies and prospective household investigations would be valuable for confirming the observed relationships and refining prevention strategies (25,26).

Overall, the present study contributes meaningful context-specific evidence showing that pediatric tuberculosis in Quetta is strongly shaped by a triad of infectious exposure, environmental risk, and nutritional vulnerability. The consistency between the descriptive exposure gradients and the adjusted regression findings strengthens confidence in the main conclusions. In high-burden, resource-constrained settings, interventions focused on household contact screening, ventilation improvement, and nutritional support are likely to be more immediately actionable than broader structural reforms alone. Future research should evaluate these factors in larger representative cohorts and examine whether integrating contact management, environmental risk reduction, and child nutrition services can measurably reduce pediatric tuberculosis incidence and improve treatment outcomes in Balochistan and similar settings (27,28).

CONCLUSION

This case–control study conducted at a tertiary pediatric center in Quetta demonstrates that household contact with a known tuberculosis case, absence of cross-ventilation, and malnutrition are the principal independent risk factors for pediatric pulmonary tuberculosis in this setting. These findings indicate that childhood tuberculosis risk is driven by the interaction of direct infectious exposure, unfavorable household environment, and compromised nutritional status. Strengthening contact tracing, improving ventilation-related household practices, and integrating nutritional assessment and support into pediatric tuberculosis prevention and care may help reduce disease burden in high-risk populations. Larger community-based studies are warranted to validate these findings and to inform regionally adapted prevention strategies for children in Balochistan.

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