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Article

Spirometric Assessment of Lung Function Impairment Among Brick Kiln Workers in Bahawalpur, Pakistan

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Abstract

Background: Brick kiln workers in Pakistan are chronically exposed to particulate matter, smoke, and combustion emissions, which may impair respiratory function. Spirometry is a standard tool to assess pulmonary health. This study evaluated lung function and associated demographic factors among brick kiln workers in Bahawalpur. **Methods:** A cross-sectional assessment was conducted among 70 randomly selected workers from seven brick kilns (April–June 2023). Spirometric parameters—Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV₁), and FEV₁/FVC ratio—were measured. Workers were classified as having normal, obstructive, or restrictive lung patterns. Correlations between age, smoking status, kiln type, and lung function were analyzed. **Results:** Mean FEV₁ was 74.3% and mean FEV₁/FVC ratio was 59.21%, indicating reduced lung function. Of the participants, 30 (42.8%) had obstructive patterns, 31 (44.2%) had restrictive patterns, and 9 (12.8%) were normal. **FEV₁ and FVC were strongly positively correlated ($r = 0.74$, $p < 0.001$). Age showed a moderate negative correlation with FVC ($r = -0.33$, $p = 0.005$), while kiln type correlated with age ($r = -0.43$, $p = 0.0003$) and smoking ($r = -0.31$, $p = 0.011$). Other associations, including smoking with lung function, were weak and non-significant. **Conclusions:** Brick kiln workers in Bahawalpur exhibit significant pulmonary impairments, with both obstructive and restrictive patterns predominating. Age and lung capacity were key determinants of respiratory function, while kiln type and smoking had limited direct effects. These results underscore the need for routine spirometry, protective measures, and regulatory interventions to reduce occupational respiratory risk.**

Keywords: spirometry; lung function; FEV₁, FEV₁/FVC; brick kilns; occupational health; air pollution

1. Introduction

Brick kilns are a major source of air pollution in South Asia, releasing particulate matter, carbon monoxide, sulfur dioxide, and nitrogen oxides. Workers in these kilns are routinely exposed to pollutants for long hours, often without protective equipment, increasing their risk of obstructive and restrictive lung diseases.

Spirometry is a non-invasive method for evaluating lung function through key indicators such as Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV₁), and the FEV₁/FVC ratio. While prior studies have documented reduced FEV₁ and FVC among brick kiln workers, few have examined how **age, smoking status, and kiln-specific factors interact with pulmonary function**.

This study aims to assess lung function among brick kiln workers in Bahawalpur, classify their respiratory patterns, and explore the correlations between lung function parameters and demographic and occupational factors. The findings will provide evidence for targeted occupational health interventions and inform policies to protect workers' respiratory health.

2. Materials and Methods

2.1. Study Area and Participants

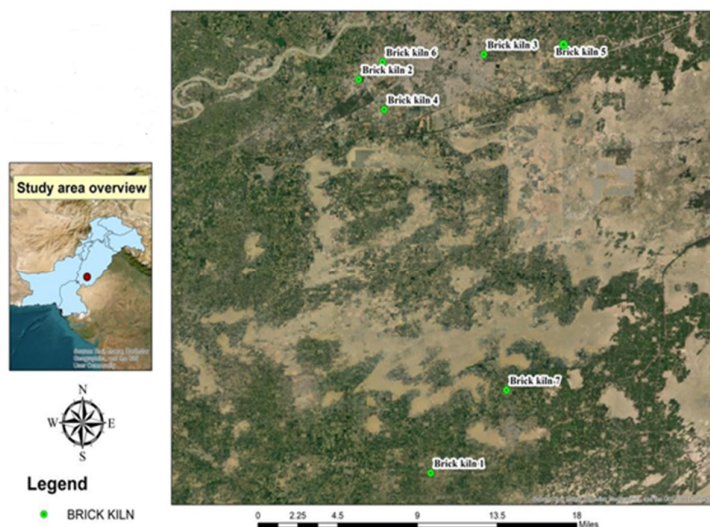


Figure 1. Location of the study area (Bahawalpur District, Punjab, Pakistan), showing the sites of the seven surveyed brick kilns.

The study was conducted between **April-June 2023** among brick kiln workers in Bahawalpur district, Southern Punjab, Pakistan. Seven kilns as well as the ten workers recruited from each kiln were selected through **random sampling**, yielding a total sample of **70 participants**. The sample included both adult and child workers, reflecting the actual composition of the brick kiln labor force.

Participation was entirely voluntary. **Written informed consent was obtained from all participants, including children, using consent forms.** For child workers, assent was obtained from the children themselves, and guardian/parental permission was sought where available. Ethical approval for the study was granted by the **Ethical Review Committee of Kinnaird College for Women, Lahore** (Approval no. KC/ORIC/ERC/2023/006)

2.2. Spirometry Procedure

Lung function was assessed using a **Geratherm Respiratory USB Pneumo Spirometer** integrated with **Blue Cherry USB Software**. Workers were tested in a standing position while wearing a nose clip. Plastic mouthpieces were used for hygiene and changed after each participant.

Each worker was instructed to:

1. Inhale fully
2. Place the mouth around the spirometer mouthpiece
3. Exhale forcefully and completely into the device

The best acceptable curve from three trials was recorded.

2.3. Parameters Measured

- **Forced Vital Capacity (FVC)**
- **Forced Expiratory Volume in 1 Second (FEV₁)**
- **FEV₁/FVC Ratio**
- **Lung Pattern Classification**

The following definitions were applied:

- **Normal:** $FEV_1/FVC \geq 70\%$ and $FEV_1 \geq 80\%$
- **Obstructive:** $FEV_1/FVC < 70\%$
- **Restrictive:** $FEV_1/FVC \geq 70\%$ with reduced FVC

(Worker-specific values, as originally recorded, were retained.)

2.4. Data Analysis

Data were entered and analyzed using descriptive statistics. Mean FEV_1 and FEV_1/FVC values were calculated. Percentages of obstructive, restrictive, and normal cases were computed. Results were compared across the sampled kilns.

3. Results

All 70 workers completed spirometry testing.

3.1. Average Lung Function

The overall mean spirometric values for the workers were:

- **Mean FVC:** 74.14%
- **Mean FEV_1 :** 74.3%
- **Mean FEV_1/FVC Ratio:** 59.21%

These results indicate reduced lung performance across the sample.

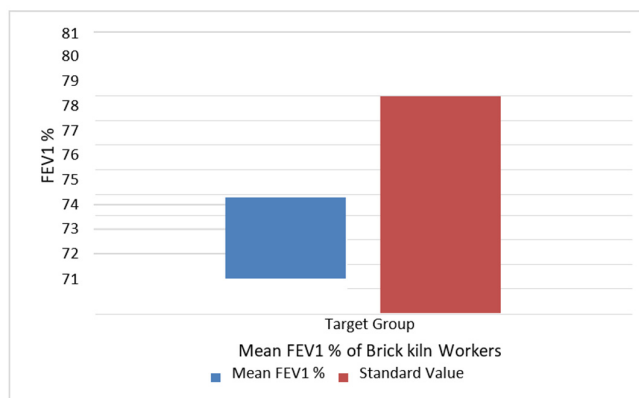


Figure 2. Comparison between FEV1% of Workers with Standard Value (Bahawalpur, April-June 2023).

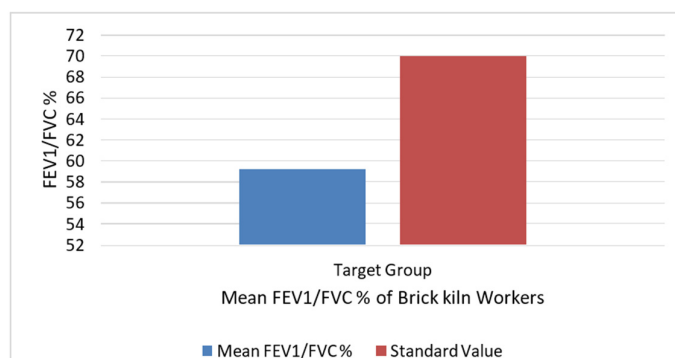


Figure 3. Comparison between FEV1/FVC% of Workers with Standard Value (Bahawalpur, April-June 2023).

3.2. Distribution of Lung Function Patterns

Among the 70 workers:

- **30 (42.8%) – Obstructive pattern**
- **31 (44.2%) – Restrictive pattern**
- **9 (12.8%) – Normal lung function**

Restrictive and obstructive impairments were nearly equal, with a slightly higher prevalence of restrictive patterns.

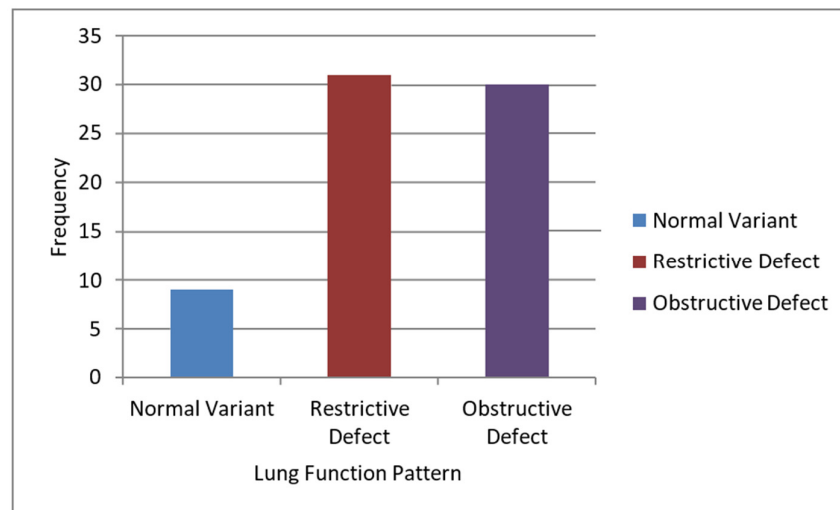


Figure 4. Lung Function Pattern of Brick kiln Workers (Bahawalpur, April-June 2023).

3.3. Kiln-Wise Comparison

Lung function varied across kilns. Across the seven brick kilns, both mean FEV1 and mean FEV1/FVC values showed noticeable variability, indicating differences in pulmonary function among workers at different sites. Mean FEV1 ranged from **67.5 to 83.1**, with the lowest value observed at *Kiln 2* and the highest at *Kiln 7*, reflecting a gradual overall improvement toward the later kilns. Similarly, mean FEV1/FVC values ranged from **54.7 to 64.9**, with *Kiln 6* showing the most pronounced reduction in airflow capacity.

Although the pattern showed fluctuations, the consistently reduced FEV1/FVC ratios across all kilns suggest a tendency toward **obstructive ventilatory impairment**, likely attributable to chronic exposure to smoke, particulate matter, and combustion by-products. The marked dips at Kilns 2 and 6 indicate potential localized factors contributing to higher respiratory stress, whereas the elevated values at Kiln 7 hint at comparatively better working or environmental conditions.

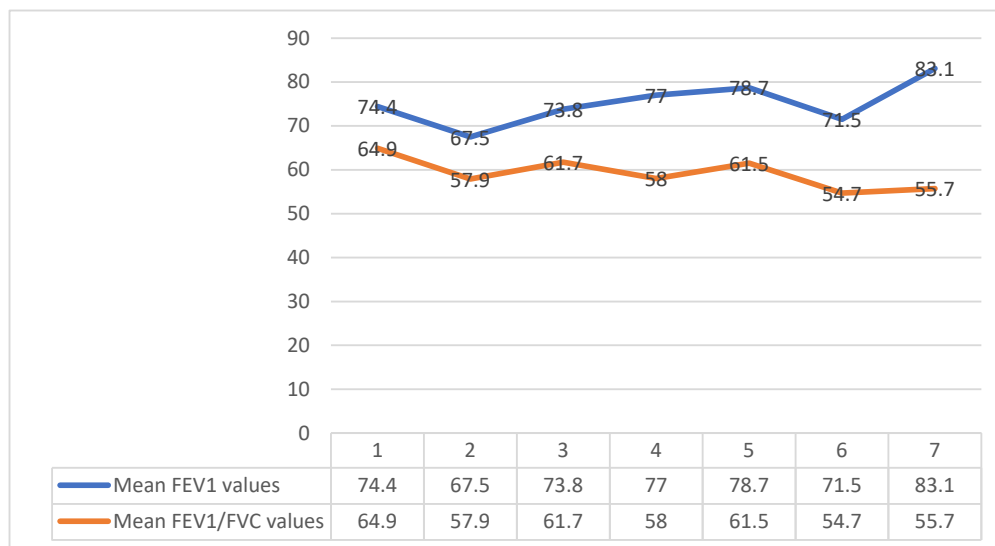


Figure 5. Variation in Pulmonary Function Indicators (FEV₁ and FEV₁/FVC) Across Seven Brick Kilns (Bahawalpur, April-June 2023).

Table 1. Correlation Matrix for Age, Smoking Status, FEV₁, and FVC Among Brick Kiln Workers (Bahawalpur, April-June 2023).

	Klin	Age	Smoker	FEV ₁	FVC
Kiln	1	-0.425**	-0.305*	-0.137	0.083
Age	-0.425**	1	0.160	-0.159	-0.325**
Smoker	-0.305*	0.160	1	-0.090	-0.142
FEV ₁	-0.137	-0.159	-0.090	1	0.740***
FVC	0.083	-0.325**	-0.142	0.740***	1

FEV₁ and FVC are strongly positively correlated ($r = 0.74$, $p < 0.001$), age is moderately negatively associated with FVC ($r = -0.33$, $p = 0.005$), kiln type correlates with age ($r = -0.43$, $p = 0.0003$) and smoking ($r = -0.31$, $p = 0.011$), while other associations, including smoking with lung function, are weak and not statistically significant.

4. Discussion

The present study demonstrates a substantial prevalence of both obstructive and restrictive lung impairments among brick kiln workers in Bahawalpur, with nearly **87%** of participants exhibiting abnormal spirometric patterns. These findings align with international research documenting pulmonary deterioration among workers exposed to biomass combustion, dust, and industrial emissions. For instance, **a study in Nepal reported that 68%** of brick kiln workers had reduced lung function, predominantly obstructive, due to chronic exposure to coal and wood smoke. Similarly, **Singh et al. (2015)** in India observed significant declines in FEV₁ and FVC among kiln laborers compared to non-exposed populations, indicating cumulative adverse effects of particulate-rich environments.

In this study, restrictive impairments were slightly more prevalent than obstructive ones, mirroring findings from **Bangladesh** where prolonged inhalation of fine particulates, silica-containing dust, and ash contributed to restrictive patterns. This distribution suggests that brick kiln workers in Bahawalpur are exposed not only to smoke but also to settled dust, clay particles, and chronic muscular strain associated with manual labor—factors commonly reported in kiln environments across South Asia.

Variation in pulmonary function across the seven kilns likely reflects differences in environmental exposures, kiln design, fuel type, and worker safety practices. Lower FEV₁ and FEV₁/FVC ratios at **Kilns 2 and 6** suggest higher concentrations of airborne pollutants such as PM_{2.5}, PM₁₀, SO₂, CO, and black carbon, which are known to impair lung function over time. Studies by

Kumar et al. (2018) and Malla & Jha (2020) similarly reported that traditional Bull's Trench and clamp kilns produce elevated emissions correlating with reduced FEV₁ and FEV₁/FVC ratios in exposed workers. Additionally, inadequate protective gear and poor ventilation have been shown to amplify the risk of obstructive respiratory changes (**Ahmad et al., 2019**). Conversely, comparatively higher spirometric values at **Kiln 7** may reflect improved kiln structures, better emission control measures, or reduced exposure duration, emphasizing the role of workplace design in mitigating respiratory risk.

Correlation analysis revealed a **strong positive association** between FEV₁ and FVC ($r = 0.74, p < 0.001$), indicating that higher lung capacity corresponds to better expiratory volumes. Age was moderately negatively correlated with FVC ($r = -0.33, p = 0.005$), reflecting age-related decline in lung function. While kiln type correlated with age ($r = -0.43, p = 0.0003$) and smoking ($r = -0.31, p = 0.011$), it was not directly associated with lung function. Smoking showed weak, non-significant associations with FEV₁ and FVC, possibly due to variability in exposure. These findings align with prior research reporting restrictive patterns among brick kiln workers (**Raza et al., 2021; Shaikh et al., 2012; Reddy et al., 1998**) and underscore age and lung capacity as key determinants of respiratory health, while occupational exposures may exert more complex or indirect effects.

The spirometric decline observed reflects broader occupational health disparities in low- and middle-income countries, where regulatory frameworks are often weak or poorly implemented. In contrast, international guidelines—such as those from **OSHA and EU-OSHA**—mandate routine exposure monitoring, provision of certified respiratory protective equipment, periodic spirometry screening, and engineering controls, which have significantly reduced respiratory morbidity among industrial workers. In Pakistan, brick kilns often operate informally with limited oversight, lack of protective devices, and no routine health surveillance. Consequently, workers experience prolonged exposure to PM_{2.5}, PM₁₀, black carbon, soot, and toxic gases such as SO₂ and NO_x. Adoption of emission-reducing technologies, such as zig-zag kilns or vertical shaft brick kilns, has been shown to reduce particulate emissions by up to 70% in countries like **Vietnam, China, and India**. The slow transition to cleaner methods in Pakistan likely contributes to the persistent respiratory burden observed in this study.

Overall, these findings reaffirm global evidence linking brick kiln work with impaired pulmonary function and highlight the urgent need to strengthen occupational safety policies and enforce environmental regulations in Pakistan. The results emphasize the universal vulnerability of kiln workers to respiratory hazards and underscore the importance of effective protective measures and policy interventions.

5. Limitations

This study has a few limitations that should be considered. Because no non-exposed control group was included, it is difficult to directly compare the lung function of brick kiln workers with individuals outside this occupation. The study also relied solely on spirometry without supporting clinical examinations or imaging, which may have provided a more complete understanding of respiratory health. Additionally, environmental pollutant levels such as PM_{2.5}, PM₁₀, SO₂, and CO were not measured alongside lung tests, limiting the ability to link specific exposures to the observed impairments. The cross-sectional design captures lung function at only one point in time, and therefore cannot show long-term trends or cumulative effects. Finally, the sample was limited to workers in Bahawalpur, which may restrict generalizability to other regions with different kiln technologies or working conditions. Despite these limitations, the study offers important evidence on respiratory risks in this understudied occupational group.

6. Conclusions

The present study contributes important evidence regarding the high burden of lung function impairments among brick kiln workers in Bahawalpur. The spirometric decline observed—characterized by both obstructive and restrictive patterns—underscores the chronic respiratory hazards associated with unregulated exposure to pollutants and dust in kiln environments. While the findings align with international research, they also highlight critical gaps in occupational health practices and environmental policy enforcement in Pakistan.

7. Theoretical Implications

This study strengthens the theoretical understanding of occupational respiratory health by confirming that long-term exposure to kiln-related pollutants leads to significant pulmonary impairment. It contributes to the existing literature by documenting a high prevalence of restrictive as well as obstructive spirometric patterns in a region where such data are limited. The findings support exposure–response theories suggesting that particulate matter, silica dust, and combustion fumes cumulatively degrade lung function over time. Additionally, the study addresses a gap in the Pakistani context, providing empirical evidence that supports global models of respiratory risk among industrial laborers in low-regulation environments.

8. Managerial and Policy Implications

The findings hold significant implications for environmental regulators, public health officials, and kiln owners. There is a clear need for:

- **Regular mandatory spirometric screening** for kiln workers.
- **Provision of certified respiratory protective equipment**, such as N95 or KN95 masks.
- **Implementation of cleaner brick kiln technologies**, including zig-zag or vertical shaft kilns, as recommended by international agencies.
- **Training programs** for workers on occupational safety and dust minimization practices.
- **Strengthening enforcement** of Pakistan's National Environmental Quality Standards (NEQS) relating to industrial emissions.

Policymakers can draw from international standards such as **OSHA guidelines**, **WHO occupational health frameworks**, and **EU-OSHA directives**, which emphasize engineering controls, exposure reduction, and routine health monitoring to prevent long-term disability.

9. Future Research Directions

Future studies should incorporate:

- **A control group** to enable more robust comparative analysis.
- **Environmental monitoring data** (PM_{2.5}, PM₁₀, SO₂, CO, NO₂) collected concurrently with spirometry to better quantify exposure–response relationships.
- **Longitudinal study designs** to track lung function deterioration over time.
- **Clinical evaluations**, including chest X-rays or diffusion capacity tests (DLCO), to complement spirometric findings.
- **Assessment of psychosocial and socioeconomic determinants** of respiratory health among kiln workers.
- **Evaluations of cleaner kiln technologies** to measure actual improvements in workers' health post-implementation.

Such research would enrich understanding of the long-term respiratory burden of brick kiln work and inform more targeted interventions.

Funding: No external funding was received.

Ethical Approval: All participants provided written consent. The study poses minimal risk as it involved non-invasive spirometry testing.

Data Availability: The datasets generated during this study are available from the author upon reasonable request.

Conflicts of Interest: The author declares no conflicts of interest.

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