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SPECTRUM OF OCCUPATIONAL DISEASES AND RESPIRATORY HEALTH AMONG BRICK KILN WORKERS IN KARNATAKA: A CROSS-SECTIONAL ANALYSIS

Biswabinod Sanfui[1], Avinash Dubey[2], Prachi Jasuja[3], Manami Das Sanfui[4]

[1]*Associate Professor, Department of Community Medicine, K D Medical College Hospital and Research Centre, Mathura Uttar Pradesh, India*
[2]*Assistant Professor, Department of Community Medicine, Saraswati Medical College, Unnao, Uttar Pradesh, India*
[3]*Senior Resident, Department of Community Medicine, Chhindwara Institute of Medical Sciences, Chhindwara, Madhya Pradesh, India*
[4]*Senior Lecturer, K D Dental College and Hospital, Mathura, Uttar Pradesh, India*

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Corresponding Author:
Dr. Biswabinod Sanfui,
Associate Professor, Department of Community Medicine, K D Medical College Hospital and Research Centre, Mathura Uttar Pradesh, India.
Email: drbinod89@gmail.com

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ABSTRACT

Background: India's brick manufacturing industry employs over 10 million workers facing significant occupational health hazards, yet comprehensive health data remain limited, particularly in Karnataka. The objective is to assess the prevalence of occupational health disorders, emphasizing respiratory dysfunction among brick factory workers in Malur Taluk, Karnataka, and to examine dose-response relationships between exposure duration and pulmonary outcomes.

Materials and Methods: A cross-sectional study of 239 brick factory workers (≥18 years) from 17 randomly selected factories in Malur Taluk, Kolar district, Karnataka was conducted. Structured questionnaires captured sociodemographic, occupational, and health data. Spirometry (using Contec SP10) was performed as per ATS/ERS guidelines measured FEV_1 , FVC, and PEFR as percent-predicted values. Statistical analysis included ANOVA, Pearson correlation, chi-square test, and linear trend analysis.

Results: The workforce comprised 160 males (67%) and 79 females (33%); mean age 34.2 ± 11.8 years. Spirometric abnormalities were detected in 76.6% of workers, with female workers (86.1%), undernourished individuals (94.4%), and those with >10 years exposure (94.8%) most affected. FEV_1 declined from 74.5 ± 18.2% predicted (≤1 year) to 57.3 ± 26.1% (>10 years; $p<0.001$); PEFR showed the steepest fall (76.9% → 56.5%; $\Delta = -20.4\%$). Strong negative Pearson correlations confirmed cumulative lung damage: PEFR ($r = -0.389$, $p<0.001$), FEV_1 ($r = -0.342$, $p<0.001$). Musculoskeletal complaints affected 33.1% of workers.

Conclusion: Brick factory workers in Karnataka face a severe occupational health crisis, with progressive respiratory impairment directly proportional to exposure duration. Comprehensive interventions including dust control, mandatory spirometry surveillance, PPE enforcement, and manufacturing modernization are urgently required.

Keywords: Brick kiln workers; occupational hazards; respiratory dysfunction; spirometry; musculoskeletal disorders; FEV_1 ; FVC; PEFR.

INTRODUCTION

India stands as the world's second-largest brick producer, manufacturing approximately 250 billion bricks annually across ~140,000 kilns, and employing over 10 million workers making it one of the largest unorganized industrial sectors in the country.[1] Despite its critical economic role, the brick manufacturing industry operates with minimal occupational health and safety regulation, exposing workers to a complex and cumulative mixture of hazardous conditions.

Brick production involves clay preparation, molding, drying, and kiln firing, each generating distinct respiratory hazards. Workers inhale high concentrations of respirable crystalline silica during clay preparation and brick handling, while the firing process releases fine particulate matter, sulfur dioxide, carbon monoxide, and other combustion byproducts.[2] The International Agency for Research on Cancer classifies crystalline silica as a Group 1 carcinogen, establishing a direct link with silicosis and lung cancer.[3] Beyond the respiratory system, the physically demanding nature of brick production involving heavy lifting, repetitive motion, prolonged standing, and work in extreme heat creates substantial musculoskeletal risks.[2]

Karnataka, a major brick-manufacturing hub in southwestern India, presents a particularly vulnerable workforce. The state's brick industry is concentrated in rural areas where workers predominantly from marginalized communities, lack access to healthcare services and occupational health protections.[3,4] Yet comprehensive cross-sectional data on pulmonary function and the full occupational disease spectrum from this region remain scarce.

Spirometry is the gold standard for objectively detecting early occupational lung disease before clinical symptoms emerge.[5] FEV_1 (forced expiratory volume in 1 second), FVC (forced vital capacity), and PEFR (peak expiratory flow rate) serve as sensitive indicators of obstructive or restrictive disease patterns developing with occupational exposure.[9–12] Despite international recommendations for routine spirometric surveillance, this is rarely implemented in India's brick sector.[5]

The socioeconomic burden of occupational respiratory disease extends beyond individual health; impaired lung function reduces work capacity, increases absenteeism, and accelerates premature retirement among workers already living in poverty.[6] Weak regulatory enforcement further compounds these vulnerabilities.[7]

This study aimed to assess the prevalence and spectrum of occupational health disorders with particular focus on spirometrically confirmed respiratory dysfunction among brick factory workers in Malur Taluk, Karnataka. We further evaluated dose-response relationships between exposure duration and spirometric parameters, and examined the modifying roles of gender, nutritional status, and smoking on pulmonary outcomes.

MATERIALS AND METHODS

A cross-sectional study was conducted from January to August 2023 among brick factory workers in Malur Taluk, Kolar district, Karnataka. From 320 factories listed by the Energy and Resources Institute (TERI), 17 facilities were systematically selected (80% facility participation rate). Factories included 8 brick-only units (47.1%), 6 tile-only units (35.3%), and 3 combined brick-tile plants (17.6%), with workforces ranging from 12 to 28 employees per site. Inclusion criteria: age ≥18 years, employment ≥6 months, and capacity to provide informed written consent. Exclusion criteria: acute respiratory illness, history of thoracic surgery, pregnancy, inability to perform adequate spirometry. Of 267 workers approached, 239 completed the protocol (89.5% response rate); 28 were excluded due to acute respiratory illness (n=12), inability to perform spirometry (n=8), pregnancy (n=3), or withdrawal of consent (n=5).

Trained investigators administered a structured questionnaire capturing sociodemographic variables (age, sex, education, socioeconomic status by modified BG Prasad scale),[8] occupational history (work duration, job designation, daily work hours, PPE use), lifestyle factors (smoking status, cooking fuel), and self-reported morbidities. Anthropometric measurements and BMI were classified using Asia-Pacific guidelines.[9] Spirometric assessment was performed using a Contec SP10 spirometer strictly following ATS/ERS 2019 guidelines.[10] The best of at least three technically acceptable manoeuvres was recorded. Outcomes were FEV_1, FVC, and PEFR expressed as percent-predicted values; values below the 5th percentile lower limit of normal were classified as abnormal.

Data were analyzed using SPSS v25.0. Categorical variables were summarized as frequencies and percentages; continuous variables as mean ± SD or median (IQR). Group comparisons used chi-square or Fisher's exact tests for categorical variables, independent-samples t-test or Mann-Whitney U test for continuous variables, and one-way ANOVA with post-hoc analysis for multi-group spirometric comparisons. Pearson correlation coefficients assessed associations between work duration and spirometric parameters. Linear trend tests evaluated dose-response relationships. Statistical significance was set at $p<0.05$.

RESULTS

The study enrolled 239 workers: 160 males (67%) and 79 females (33%), with a mean age of 34.2 ± 11.8 years. Educational attainment was low: 57.7% had no formal schooling, markedly higher in females (75.9% vs 48.8% in males). The majority belonged to socioeconomic classes II–III (79.5%). Median work duration was 60 months (IQR 24–120); 24.3% had worked >10 years. A substantial proportion 67 (28.0%) were current smokers, predominantly males (38.8% vs 6.3% in females). Demographic and exposure characteristics are summarised in [Table 1].

Table 1: Demographic and Occupational Characteristics of Brick Factory Workers (N=239)

Variable	Category	Total (N=239)	Male (n=160)	Female (n=79)
Age Group	Young adult (<30 yr)	109 (45.6%)	77 (48.1%)	32 (40.5%)
	Middle adult (30–50 yr)	103 (43.1%)	66 (41.3%)	37 (46.8%)
	Senior adult (>50 yr)	27 (11.3%)	17 (10.6%)	10 (12.7%)
	Mean Age ± SD (years)	34.2 ± 11.8	33.8 ± 12.1	35.1 ± 11.2
Socioeconomic Status	Class I	25 (10.5%)	19 (11.9%)	6 (7.6%)
	Class II	107 (44.8%)	66 (41.3%)	41 (51.9%)
	Class III	83 (34.7%)	55 (34.4%)	28 (35.4%)
	Class IV–V	24 (10.0%)	20 (12.5%)	4 (5.1%)
Smoking Status	Never smoker	156 (65.3%)	87 (54.4%)	69 (87.3%)
	Current smoker	67 (28.0%)	62 (38.8%)	5 (6.3%)
	Former smoker	16 (6.7%)	11 (6.9%)	5 (6.3%)
Work Duration	Median (IQR) months	60 (24–120)	60 (18–108)	96 (36–144)
	≤1 year	27 (11.3%)	23 (14.4%)	4 (5.1%)
	>1–5 years	99 (41.4%)	66 (41.3%)	33 (41.8%)
	>5–10 years	55 (23.0%)	37 (23.1%)	18 (22.8%)
	>10 years	58 (24.3%)	34 (21.3%)	24 (30.4%)
BMI Category	Undernourished (<18.5)	54 (22.6%)	32 (20.0%)	22 (27.8%)
	Normal (18.5–22.9)	111 (46.4%)	78 (48.8%)	33 (41.8%)
	Overweight (23.0–24.9)	38 (15.9%)	27 (16.9%)	11 (13.9%)
	Obese (≥25.0)	36 (15.1%)	23 (14.4%)	13 (16.5%)

IQR = interquartile range; BG Prasad scale: Class I (highest) to Class V (lowest socioeconomic status); BMI classified per Asia-Pacific cut-offs.

Musculoskeletal complaints constituted the most common self-reported morbidities: generalised body pain (16.7%), localised pain (16.3%), and generalised weakness (2.1%). Respiratory symptoms were prevalent: dry cough (8.8%), running nose (6.7%), and throat irritation (3.4%). Other morbidities included gastrointestinal complaints (6.7%), occupational injuries (5.4%), hypertension (3.4%), and dermatological disorders (3.4%). Breathlessness was reported by 1.7% and clinician-diagnosed asthma by 0.4%.

Overall, 183 of 239 workers (76.6%) demonstrated abnormal spirometry. A clear and statistically significant dose-response relationship was identified between work duration and all three spirometric parameters. [Table 2] shows that FEV_1 declined from 74.5 ± 18.2% predicted in workers with ≤1 year exposure to 57.3 ± 26.1% in those with >10 years (absolute reduction −17.2%; p<0.001). FVC fell from 67.1% to 56.7% (−10.4%; p=0.008), and PEFR exhibited the most deterioration from 76.9% to 56.5% (−20.4%; p<0.001). Linear trend analysis confirmed monotonic decline for all parameters (FEV_1 and PEFR: p<0.001; FVC: p=0.002). Pearson correlation confirmed strong negative associations between work duration and PEFR (r = −0.389), FEV_1 (r = −0.342), and FVC (r = −0.198), all significant at p<0.001.

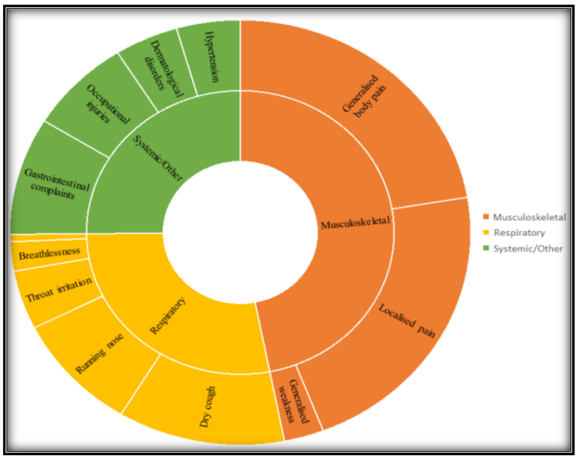

Figure 1: Hierarchical Distribution of Self-Reported Morbidities Among Study Participants (n = 239).

Table 2: Spirometric Parameters by Work Duration and Correlation Coefficients: Dose-Response Analysis

Work Duration	n	FEV_1 % pred (±SD)	FVC % pred (±SD)	PEFR % pred (±SD)	p-value (ANOVA)
≤1 Year (Reference)	27	74.5 ± 18.2	67.1 ± 16.8	76.9 ± 22.1	,
>1–5 Years	99	69.5 ± 22.4	63.9 ± 21.2	70.0 ± 25.6	<0.001*
>5–10 Years	55	62.9 ± 24.8	58.0 ± 23.4	64.3 ± 28.2	<0.001*
>10 Years	58	57.3 ± 26.1	56.7 ± 24.6	56.5 ± 30.8	<0.001*
Absolute Reduction (≤1yr → >10yr)	,	−17.2%	−10.4%	−20.4%	,
Linear Trend (p-value)	,	<0.001	0.002	<0.001	,
Pearson r (work duration)	,	−0.342 (p<0.001)	−0.198 (p=0.002)	−0.389 (p<0.001)	,

Values expressed as mean ± SD (% predicted). *p<0.001 vs reference group (≤1 year), ANOVA with post-hoc analysis. Linear trend and Pearson correlation (r) computed using work duration as continuous variable. CI = confidence interval.

[Table 3] shows that male workers demonstrated significantly superior lung function across all parameters: FEV_1 68.7% vs 59.4% (p=0.002), FVC 64.0% vs 55.4% (p=0.002), and PEFR median 64.5 vs 59.0 (p=0.020). Notably, the rate of spirometric deterioration with increasing work duration was steeper in females than males. Workers who had never smoked had significantly higher FEV_1 (68.2%) compared to current (60.4%) and former smokers (58.9%; ANOVA p=0.017), with similar patterns for FVC and PEFR. Combined brick-tile factory workers had the highest prevalence of respiratory abnormalities (78.9%), followed by brick-only (64.5%) and tile-only units (58.3%; p=0.041). Only 34 workers (14.2%) consistently used personal protective equipment; usage was significantly higher among supervisors vs. production workers (p<0.001).

Table 3: Gender- and Smoking-Stratified Spirometric Parameters

Subgroup	N	FEV_1 % pred (mean ± SD)	FVC % pred (mean ± SD)	PEFR % pred (median, IQR)
By Gender				
Male	160	68.7 ± 24.2 [95% CI: 64.9–72.5]	64.0 ± 22.7 [95% CI: 60.4–67.5]	64.5 (IQR 45–89)
Female	79	59.4 ± 21.4 [95% CI: 54.6–64.1]	55.4 ± 20.1 [95% CI: 50.9–59.9]	59.0 (IQR 43–71)
p-value (M vs F)	,	p = 0.002*	p = 0.002*	p = 0.020†
By Smoking Status				
Never Smokers	156	68.2 ± 22.8	63.8 ± 21.4	66.8 ± 26.2
Current Smokers	67	60.4 ± 25.1	57.1 ± 23.8	58.3 ± 28.4
Former Smokers	16	58.9 ± 24.6	56.2 ± 22.9	55.1 ± 27.8
p-value (ANOVA)	,	p = 0.017*	p = 0.032*	p = 0.009*

*Independent samples t-test (FEV_1 , FVC); †Mann-Whitney U test (PEFR). ANOVA used for smoking group comparisons, adjusted for age and work duration. CI = confidence interval; IQR = interquartile range.

Risk factor associations with spirometric classification are summarised in Table 4. Female sex (p=0.007), older age (p=0.007), undernutrition (p<0.001), greater work duration (p<0.001), active smoking (p=0.024), and kerosene use for cooking (100% abnormal, p=0.033) were all significantly associated with abnormal spirometry. The prevalence of abnormality rose from 44.4% among workers with ≤1 year exposure to 94.8% in those with >10 years, an absolute increase of 50.4 percentage points.

Table 4: Association of Sociodemographic and Occupational Risk Factors with Abnormal Spirometry (N=239)

Risk Factor	Normal Spirometry n (%)	Abnormal Spirometry n (%)	Total	p-value
Gender				
Male	45 (28.1%)	115 (71.9%)	160	0.007
Female	11 (13.9%)	68 (86.1%)	79	
Age Group				
<30 years	35 (32.1%)	74 (67.9%)	109	0.007
30–50 years	18 (17.5%)	85 (82.5%)	103	
>50 years	3 (11.1%)	24 (88.9%)	27	
BMI Category (Asia-Pacific)				
Undernourished (<18.5)	3 (5.6%)	51 (94.4%)	54	<0.001
Normal (18.5–22.9)	41 (36.9%)	70 (63.1%)	111	
Overweight (23.0–24.9)	6 (15.8%)	32 (84.2%)	38	
Obese (≥25.0)	6 (16.7%)	30 (83.3%)	36	
Work Duration				
≤1 year	15 (55.6%)	12 (44.4%)	27	<0.001
>1–5 years	30 (30.3%)	69 (69.7%)	99	
>5–10 years	8 (14.6%)	47 (85.5%)	55	
>10 years	3 (5.2%)	55 (94.8%)	58	
Smoking Status				
Smoker	6 (11.8%)	45 (88.2%)	51	0.024
Non-Smoker	50 (26.6%)	138 (73.4%)	188	
Cooking Fuel				
Wood	32 (25.8%)	92 (74.2%)	124	0.033
Kerosene	0 (0.0%)	31 (100.0%)	31	
Wood & Kerosene	19 (23.2%)	63 (76.8%)	82	
LPG	5 (21.7%)	18 (78.3%)	23	
OVERALL ABNORMAL SPIROMETRY	183 / 239 (76.6%)	239		

Chi-square test used throughout. p-values in red indicate statistical significance (p<0.05). Abnormal spirometry defined as below the 5th percentile lower limit of normal for age- and sex-predicted values.

DISCUSSION

This cross-sectional study of 239 brick factory workers in Malur Taluk, Karnataka, documents a severe and pervasive occupational respiratory health crisis. The 76.6% prevalence of spirometric abnormalities substantially exceeds rates reported in comparably exposed industrial cohorts, typically 5–30%,[11-13] and closely mirrors the 78.3% prevalence reported among brick kiln workers in Kasur, Pakistan, where 95% of abnormalities were restrictive in pattern.[14]

The dose-response evidence is compelling. FEV_1 declined by 17.2% predicted over a decade, nearly fourfold the 4.5% per-decade decline reported in Indian brick kiln workers with >8 years of exposure.[16] The parallel FVC reduction (67.1% → 56.7%) mirrors restrictive patterns attributed to silica-induced interstitial fibrosis in Pakistani brick workers,[15] while the disproportionate PEFR decline (−20.4%) reflects predominant small-airway dysfunction, a hallmark of pneumoconiosis driven by fine particulate matter inhalation.[14] Biochemical studies documenting elevated malondialdehyde and depleted glutathione in brick workers with >5 years exposure provide a mechanistic basis for this accelerated pulmonary decline.[14]

The steeper trajectory in our study may reflect elevated ambient PM and synergistic exposure to silica and combustion byproducts characteristic of Karnataka's Malur kiln cluster. The TERI cluster profile confirms high dust generation from mixed clay and fired-brick operations in this area.[4] A 2024 systematic review and meta-analysis confirmed that silica exposures in brick kilns frequently exceed guideline limits (up to 620 µg/m³) and are consistently associated with spirometric impairment.[15-18]

The higher burden of respiratory dysfunction in females (86.1% vs 71.9%; p=0.007) likely reflects multiple compounding factors: task-specific exposures (females predominantly perform high-dust molding and brick-carrying), domestic biomass fuel exposure, physiologically smaller airways, and relative absence of respiratory conditioning from physical training.[19,20] Studies from rural North India have similarly demonstrated higher respiratory morbidity prevalence in female brick kiln workers ($p<0.05$).[15]

The striking association between undernutrition and respiratory dysfunction (94.4% abnormal) highlights the intersection of occupational and social determinants of health. Malnutrition compromises innate and adaptive immune defenses, increasing susceptibility to occupational lung disease and reducing capacity for pulmonary repair.[25-27] This finding has direct implications for nutrition supplementation programmes in the brick sector.

Current smokers showed significantly lower FEV_1 (−7.8 percentage points) and PEFR (−8.5 percentage points) vs. never-smokers, demonstrating additive respiratory impairment beyond occupational exposure, consistent with a synergy index of 2.25 reported among rubber industry workers exposed to occupational hazards combined with smoking.[21] Smoking cessation thus represents a modifiable priority alongside dust control.

PEFR emerged as the most sensitive early indicator of occupational damage (r = −0.389), preceding FEV_1 /FVC ratio changes, consistent with its utility in monitoring small-airway dysfunction in other particulate-exposed occupational groups.[23-25] Only 14.2% of production workers used PPE consistently, a critical safety gap that urgently demands systems-level intervention.

Our findings align with international evidence: studies from Patiala,[19] and Bhaktapur, Nepal[20] documented significant lung function decline with increasing silica exposure duration; the Nawabshah cohort showed COPD confirmed by spirometry in 18.9% of kiln workers vs 2.6% controls.[18] collectively; the burden appears broadly consistent across South Asian contexts with variable dust intensities.[28-30]

Several limitations warrant acknowledgment. The cross-sectional design precludes causal inference and may underestimate true burden via healthy worker effect bias. Quantitative dust and silica exposure measurements, which would strengthen dose-response conclusions, were not performed. The absence of a non-exposed comparator group limits attributable fraction estimation. Furthermore, generalizability beyond Malur Taluk's specific production practices warrants caution.

CONCLUSION

Brick factory workers in Karnataka face an unacceptable occupational health crisis. Spirometric abnormalities affect three-quarters of the workforce, with severity directly and progressively linked to exposure duration. Female workers and undernourished individuals bear disproportionately greater respiratory impairment. The consistent dose-response relationship across FEV_1, FVC, and PEFR, driven by cumulative silica and particulate inhalation, represents one of the highest rates of occupational respiratory dysfunction in the industrial literature. Musculoskeletal disorders compound the already severe burden.

Urgent, multi-stakeholder action is required: implementation of engineering dust controls (wet suppression, enclosed processes), mandatory pre-employment and periodic spirometry surveillance, universal PPE provision with enforced compliance, targeted smoking cessation and nutritional support programmes, and modernisation of kiln technology. Government regulatory agencies, industry, and public health authorities must act collectively and immediately to protect this highly vulnerable workforce.

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