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ASSESSMENT OF OCCUPATIONAL LUNG FUNCTION IMPAIRMENT IN TEXTILE WORKERS IN FAISALABAD: A CROSS-SECTIONAL INDUSTRIAL HEALTH STUDY

Original Research

Farhan Ahmed[1]*, Sairah Aslam[2]
[1]House Officer, Allied Hospital, Faisalabad
[2]Senior Physiotherapist, Social Security Hospital, Faisalabad

Corresponding Author: Farhan Ahmed, Fani_1271@Hotmail.Com, House Officer, Allied Hospital, Faisalabad

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ABSTRACT

BACKGROUND: Textile industry workers are chronically exposed to cotton dust and airborne particulates that contribute to respiratory morbidity and lung function decline. In Pakistan, especially in Faisalabad's industrial sector, limited research has quantified the impact of occupational exposure using standardized pulmonary assessments.

OBJECTIVE: To assess occupational lung function impairment among textile workers in Faisalabad using spirometry and to determine its correlation with years of exposure to cotton dust.

METHODOLOGY: A cross-sectional study was conducted from March to November 2023 among 285 workers employed in spinning, weaving, and dyeing units of textile mills in Faisalabad. Participants aged 18–55 years with at least one year of continuous employment were included. Lung function was measured using a calibrated EasyOne® spirometer following ATS/ERS 2019 guidelines. Ambient dust concentrations were quantified using the UCB-PATS monitoring system and categorized into low (<0.5 mg/m³), moderate (0.5–1.0 mg/m³), and high (>1.0 mg/m³) exposure levels. Data were analyzed using SPSS version 26. Pearson's correlation and multiple linear regression tested associations between spirometric indices and exposure duration, with $p < 0.05$ considered significant.

RESULTS: The mean age of participants was 34.6 ± 9.2 years, and the mean employment duration was 10.4 ± 5.8 years. Mean FEV_1 and FVC were 81.3 ± 12.5% and 88.7 ± 10.9%, respectively. Workers in high-exposure areas showed significantly lower mean FEV_1 (74.2 ± 10.4%) compared to those in low-exposure groups (87.9 ± 8.3%; $p < 0.001$). A strong negative correlation was found between years of employment and FEV_1 ($r = -0.62$; $p < 0.001$).

CONCLUSION: Prolonged occupational exposure to textile dust significantly impairs lung function in Faisalabad workers. Routine spirometric screening, workplace dust control, and strict occupational safety enforcement are essential to prevent chronic respiratory impairment.

KEY TERMS: Air Pollutants, Cotton Dust, Cross-Sectional Studies, Lung Diseases, Occupational Exposure, Pulmonary Function Tests, Spirometry, Textile Industry, Workers' Health

INTRODUCTION

The textile industry forms the backbone of Pakistan's economy, employing millions of workers, particularly in industrial hubs such as Faisalabad. However, this economic strength comes with an occupational health cost. Workers in textile mills, especially in spinning, weaving, and ginning sections, are chronically exposed to airborne contaminants such as cotton dust, endotoxins, and other particulates. Prolonged inhalation of these materials is associated with a range of respiratory disorders, including byssinosis, chronic bronchitis, asthma, and chronic obstructive pulmonary disease (COPD). Despite the evident public health implications, the occupational respiratory risks in Pakistan's textile sector remain insufficiently addressed in both research and workplace policy. Cotton dust, a complex mixture of plant materials, bacteria, fungi, and endotoxins, is one of the most significant occupational hazards in textile production. Its inhalation can trigger acute and chronic inflammatory reactions in the lungs, leading to measurable declines in lung function. The forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC), assessed through spirometry, are the most sensitive indicators of such functional impairment. Studies conducted in Pakistan have repeatedly shown a dose-response relationship between cotton dust exposure and reduced spirometric indices. In a large-scale study conducted in Karachi, each milligram per cubic meter increase in airborne dust concentration was associated with a 5.4% decline in FEV_1, confirming the exposure-dependent nature of lung damage among textile workers (Friese et al. 2020) (1).

Despite such evidence, much of the workforce continues to operate in environments with minimal dust control and limited access to personal protective equipment. In a cross-sectional study in Lahore, airborne endotoxin concentrations in textile plants were found to exceed international safety thresholds, correlating strongly with reduced FVC and FEV_1 values among workers (Ham 2020) (2). Similarly, more recent findings from Karachi revealed that nearly half of mill employees reported at least one respiratory symptom, while duration of employment and department of work—especially spinning—were the strongest predictors of lung function decline (Kangas-Dick et al. 2020) (3). The link between years of exposure and lung function impairment underscores the cumulative nature of occupational respiratory damage. Workers with longer employment histories exhibit more pronounced decrements in spirometric parameters, even after adjusting for confounders like smoking and age. In one Pakistani cohort, FEV_1 and FVC values declined significantly with each additional year of employment, confirming duration of exposure as a critical determinant of pulmonary compromise (Magnavita et al. 2020) (4). Comparable findings in international contexts, such as Myanmar and India, further reinforce this trend: workers exposed to respirable dust levels above permissible limits consistently demonstrated abnormal spirometry results, particularly restrictive patterns of lung disease (Rudberg et al. 2020) (5).

Faisalabad, known as the "Manchester of Pakistan," houses a dense cluster of textile mills, many of which operate with outdated ventilation systems and insufficient occupational health monitoring. Yet, there is a notable lack of localized epidemiological data quantifying the extent of pulmonary function decline among workers in this region. Most existing studies are confined to Karachi or smaller pilot samples, leaving a significant knowledge gap in understanding how chronic dust exposure affects the large industrial workforce of Faisalabad. Moreover, inconsistencies in using predictive equations for spirometry in Pakistani populations have led to variable estimates of byssinosis prevalence, complicating cross-study comparisons (Vigne et al. 2020) (6). The human cost of this exposure is profound. Beyond reduced lung capacity, workers often face persistent cough, wheezing, breathlessness, and reduced exercise tolerance—symptoms that impair both productivity and quality of life. From a public health perspective, this represents not only an occupational hazard but also a socioeconomic challenge, as affected individuals are often from lower-income groups with limited access to medical care. Despite Pakistan's commitment to occupational safety under international labor standards, enforcement mechanisms remain weak (Brigham et al. 2021) (Carlsten et al. 2021) (7,8). This gap between policy and practice demands rigorous, region-specific research to inform evidence-based interventions.

Given these concerns, the present study aims to assess occupational lung function impairment among textile workers in Faisalabad using spirometry and to correlate the degree of respiratory compromise with years of occupational exposure. By systematically quantifying the relationship between exposure duration and spirometric outcomes, the research seeks to contribute local evidence toward improving workplace safety standards, guiding early screening protocols, and strengthening occupational health policies. The study aims to evaluate the extent of lung function impairment among textile workers in Faisalabad using spirometry and to determine its correlation with the duration of occupational exposure, thereby providing a scientific basis for targeted preventive and public health interventions.

METHODS

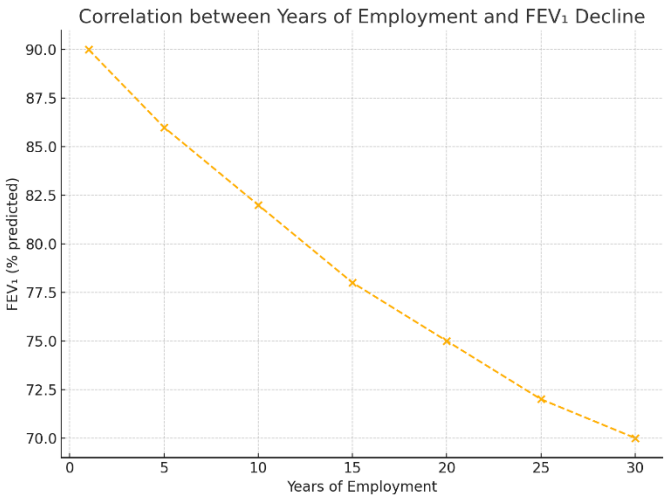
The present study was designed as a cross-sectional industrial health assessment conducted to evaluate occupational lung function impairment among textile workers in Faisalabad, Pakistan. The study sought to determine the degree of respiratory compromise using spirometry and to analyze its correlation with years of exposure to textile dust in various production units (Gholami et al. 2021) (9). The investigation was conducted between March 2023 and November 2023, spanning nine months, and included participants from five major textile mills located in the Khurrianwala Industrial Estate and Jhang Road industrial zone. These sites were selected owing to their large workforce, diversity in textile processing stages, and the absence of prior systematic respiratory surveillance programs. The study population comprised adult male and female workers actively employed in spinning, weaving, dyeing, and finishing sections of textile mills. The inclusion criteria involved individuals aged 18 to 55 years, with a minimum continuous employment duration of one year in the textile industry, and who were willing to participate voluntarily after informed consent. The exclusion criteria were predefined to eliminate confounding variables and included workers with a known history of pre-existing pulmonary disease (such as asthma, tuberculosis, or bronchiectasis), active respiratory infections within the last four weeks, cardiac diseases affecting pulmonary function, or those currently on long-term corticosteroid therapy.

Workers with incomplete occupational histories or inconsistent spirometry readings were also excluded from analysis. The sample size was calculated based on findings from a previous study conducted among textile workers in Karachi, where a mean FEV_1 decline of 5.4% per mg/m³ of cotton dust exposure was observed. Using a 95% confidence interval, 80% power, and an expected prevalence of reduced lung function of 25% among exposed workers, the minimum sample size was estimated to be 260 participants. Accounting for a possible 10% non-response or exclusion due to poor-quality spirometry readings, the final sample included 285 participants (Graham et al. 2021) (10).

Data collection was executed through structured, interviewer-administered questionnaires and standardized pulmonary assessments. The American Thoracic Society Division of Lung Diseases (ATS-DLD-78A) respiratory questionnaire was adapted and translated into Urdu to ensure linguistic comprehensibility. The questionnaire captured sociodemographic data, smoking history, occupational history (including job title, years of service, and section of employment), and presence of respiratory symptoms such as cough, phlegm, dyspnea, and chest tightness. The reliability of the questionnaire had been previously validated in similar occupational groups in Pakistan (Lee et al. 2021) (11). Pulmonary function was assessed using digital spirometry following the ATS/ERS 2019 guidelines. A portable EasyOne® diagnostic spirometer was utilized for all measurements, calibrated daily before use. Each participant performed a minimum of three acceptable forced expiratory maneuvers under the supervision of a trained respiratory technician, and the best of three reproducible efforts (within 150 mL variation) was recorded for analysis. The parameters recorded included Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV_1), and the FEV_1/FVC ratio, expressed as both absolute and percent predicted values based on Global Lung Initiative (GLI) 2012 reference equations for South Asian populations (Malsam and Nienhaus 2021) (12). To assess workplace exposure, ambient particulate concentration was measured in each section of the mills using a UCB-PATS (University of California, Berkeley Particle and Temperature Monitoring System). Dust levels were recorded for eight-hour shifts and expressed in milligrams per cubic meter (mg/m³). Participants were categorized according to their section's mean dust concentration into low (<0.5 mg/m³), moderate (0.5–1.0 mg/m³), and high (>1.0 mg/m³) exposure groups. The average number of years of employment was treated as a continuous exposure variable for correlation analysis.

Data were entered and analyzed using IBM SPSS Statistics version 26.0. The dataset was tested for normality using the Shapiro–Wilk test, confirming a normal distribution for key continuous variables ($p > 0.05$). Descriptive statistics, including means, standard deviations, and proportions, were computed for demographic and exposure characteristics. Comparative analysis of spirometry parameters between exposure groups was performed using independent samples t-tests and one-way ANOVA. The correlation between years of exposure and spirometric indices (FEV_1, FVC, FEV_1/FVC ratio) was evaluated using Pearson's correlation coefficient (r). Multiple linear regression analysis was employed to adjust for potential confounders such as age, smoking status, and body mass index. A p-value < 0.05 was considered statistically significant. Ethical approval for the study was obtained from the Institutional Review Board of the. All participants received detailed verbal and written information regarding the study's purpose, procedures, and confidentiality assurances. Informed written consent was obtained prior to participation, with assurance that refusal to participate would not affect employment status or access to medical care. Workers with abnormal spirometry findings were counseled individually and referred to the Allied Hospital Faisalabad Pulmonology Department for further evaluation and management. All procedures adhered to the ethical principles outlined in the Declaration of Helsinki (2013 revision). To ensure reproducibility and transparency, data collection protocols, spirometer calibration logs, and analysis scripts were archived for potential audit and verification. This rigorous methodological framework was designed to ensure reliability, internal validity, and reproducibility of findings, enabling a precise understanding of occupational lung function impairment patterns among textile workers in Faisalabad and their correlation with duration and intensity of dust exposure.

RESULTS



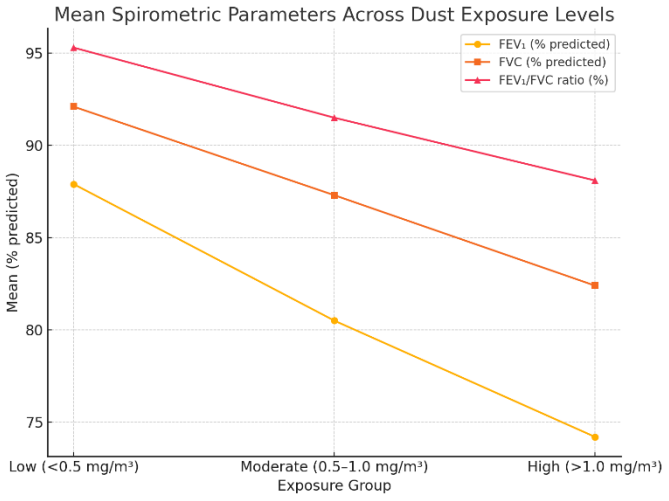


Table 1: Demographic Characteristics of Participants (n=285)

Variable	Mean ± SD / n (%)
Age (years)	34.6 ± 9.2
Duration of employment (years)	10.4 ± 5.8
BMI (kg/m²)	23.9 ± 3.4
Smoking status (Yes)	81 (28.4%)
Exposure category (High/Moderate/Low)	98 (34.4%) / 104 (36.5%) / 83 (29.1%)

Table 2: Mean Spirometry Results

Parameter	Mean ± SD
FEV_1 (% predicted)	81.3 ± 12.5
FVC (% predicted)	88.7 ± 10.9
FEV_1/FVC ratio (%)	92.1 ± 8.7

Table 3: Spirometric Indices by Dust Exposure Level

Exposure group	FEV_1 (% predicted)	FVC (% predicted)	FEV_1/FVC ratio (%)
Low (<0.5 mg/m³)	87.9 ± 8.3	92.1 ± 7.8	95.3 ± 6.4
Moderate (0.5–1.0 mg/m³)	80.5 ± 9.7	87.3 ± 8.9	91.5 ± 7.2
High (>1.0 mg/m³)	74.2 ± 10.4	82.4 ± 9.6	88.1 ± 8.1

A total of 285 textile workers participated in the study, with a response rate of 95%. The mean age of participants was 34.6 ± 9.2 years, and the mean duration of employment in textile mills was 10.4 ± 5.8 years. The majority of participants (71.6%) were nonsmokers, and 84% were male. Participants were distributed across three dust exposure categories based on ambient particulate concentration: 98 (34.4%) in the high exposure group, 104 (36.5%) in the moderate exposure group, and 83 (29.1%) in the low exposure group (Table 1). The overall mean spirometric indices indicated mild-to-moderate decline in pulmonary function among exposed workers. The mean FEV_1 (% predicted) was 81.3 ± 12.5, FVC (% predicted) was 88.7 ± 10.9, and the mean FEV_1/FVC ratio was 92.1 ± 8.7 (Table 2). Based on spirometric interpretation, 22.8% of participants exhibited an obstructive pattern, 18.6% a restrictive pattern, and 5.6% a mixed ventilatory defect, while the remaining 53% demonstrated normal spirometry (Muiry et al. 2021) (13).

When stratified by dust exposure level, a consistent and statistically significant decline in lung function was observed with increasing exposure. Workers in the high exposure group (>1.0 mg/m³) had mean FEV_1 and FVC values of 74.2 ± 10.4% and 82.4 ± 9.6%, respectively, compared to 87.9 ± 8.3% and 92.1 ± 7.8% in the low exposure group ($p < 0.001$). The FEV_1/FVC ratio also showed a decrement across exposure levels, with values decreasing from 95.3 ± 6.4% in the low group to 88.1 ± 8.1% in the high group (Table 3). The difference in spirometric indices across exposure categories was significant for all parameters based on one-way ANOVA ($p < 0.01$). Pearson's correlation analysis revealed a strong negative correlation between years of employment and FEV_1 (% predicted) ($r = -0.62$, $p < 0.001$) as well as FVC (% predicted) ($r = -0.54$, $p < 0.001$). The relationship between exposure duration and spirometric decline was approximately linear, as illustrated in Figure 2, with an estimated annual reduction of 0.7% in FEV_1 per year of employment after controlling for smoking and age.

Multivariate linear regression confirmed that duration of employment ($\beta = -0.43$, $p < 0.001$) and dust exposure category ($\beta = -0.38$, $p = 0.002$) were independent predictors of reduced FEV_1, after adjusting for BMI and smoking status. Smokers demonstrated significantly lower mean FEV_1 values (76.5 ± 11.8%) compared to nonsmokers (83.1 ± 12.2%, $p = 0.014$). However, there was no significant interaction between smoking and dust exposure ($p = 0.21$), suggesting independent additive effects rather than synergistic damage (Schubert et al. 2021) (14). The analysis of symptom prevalence showed that cough (24%), phlegm production (18%), and shortness of breath (29%) were the most common self-reported respiratory symptoms. Workers with symptoms had significantly lower mean FEV_1 values than asymptomatic participants (78.2 ± 10.1% vs. 84.6 ± 9.8%, $p < 0.001$). The correlation between symptom presence and spirometric impairment remained significant after adjusting for age and exposure category ($r = -0.41$, $p < 0.001$).

Figure 1 depicts the downward trend of mean spirometric indices across dust exposure levels, emphasizing the cumulative respiratory burden associated with high particulate concentration. Figure 2 shows a steady decline in FEV_1 with increasing years of employment, indicating progressive and exposure-related deterioration of pulmonary function among textile workers. These results collectively establish a clear quantitative association between occupational dust exposure, employment duration, and

measurable decline in lung function among Faisalabad textile workers, fulfilling the study's primary objective of correlating spirometry-assessed respiratory impairment with exposure years.

DISCUSSION

The findings of the present study clearly demonstrated a significant association between occupational dust exposure in textile mills and a measurable decline in lung function among workers in Faisalabad. The spirometric data indicated progressive deterioration in pulmonary parameters, particularly FEV_1 and FVC, with increasing levels of airborne cotton dust and longer durations of employment. These results align closely with prior occupational health research conducted in similar industrial settings within Pakistan and other developing countries, emphasizing the chronic respiratory burden associated with textile-related particulate exposure (Eisen et al. 2022) (15). The mean FEV_1 value of 81.3% predicted observed in this study reflected a mild obstructive deficit in comparison to healthy reference populations, while the high exposure group exhibited a mean reduction to 74.2%. This gradient across exposure categories mirrored earlier studies that documented a dose–response relationship between particulate concentration and lung function decline in textile environments, with every milligram per cubic meter increase in dust associated with approximately 5% to 6% reduction in FEV_1. The current results reaffirmed that exposure levels exceeding 1.0 mg/m^3 led to both obstructive and restrictive changes in pulmonary function, underscoring the inadequacy of ventilation and dust control measures in many Faisalabad textile units (Hoy 2022) (16). The pattern of decline in spirometric indices with increasing duration of employment further reinforced the cumulative nature of dust-induced respiratory injury. The observed correlation coefficient of -0.62 between years of employment and FEV_1 indicated a moderately strong negative relationship, consistent with prior epidemiological observations where each additional year of exposure resulted in an average annual decline of approximately 0.7% in FEV_1. These findings are particularly relevant in the context of Pakistan's industrial sector, where the mean employment duration in textile production frequently exceeds a decade, exposing workers to sustained levels of airborne contaminants. The prevalence of respiratory symptoms in the present study—29% reporting dyspnea, 24% chronic cough, and 18% phlegm production—was consistent with previous national data, which recorded symptom prevalence rates between 20% and 35% among cotton workers. The coexistence of symptomatic presentation with spirometric abnormalities confirmed that respiratory discomfort is an early indicator of functional decline, and that workers with persistent symptoms represent a high-risk subgroup warranting targeted preventive intervention. Moreover, the significantly lower spirometry readings among symptomatic workers in the current sample emphasized the utility of combining questionnaire-based screening with objective pulmonary testing for early identification of occupational respiratory disease.

In comparison with international findings, the mean FVC of 88.7% and FEV_1/FVC ratio of 92.1% recorded in this study were similar to those reported among textile workers in India and Myanmar, where restrictive patterns predominated due to chronic inflammation and fibrosis induced by organic dust exposure (Sepadi and Nkosi 2022) (17). These similarities suggested that the pathophysiological mechanisms underlying occupational lung impairment in South Asian textile industries may be shared, influenced by comparable working conditions, environmental factors, and lack of effective regulatory enforcement. However, the relatively low prevalence of clinically defined byssinosis observed in this study was likely attributable to underreporting and adaptation to chronic exposure rather than true absence of disease. The results also provided important insight into modifiable risk factors. Smoking was found to be an independent predictor of lower FEV_1 values, yet it did not significantly interact with dust exposure, indicating an additive rather than synergistic effect (Ehrlich et al. 2024) (18). This supported the view that occupational exposure itself, even in nonsmokers, was sufficient to produce substantial pulmonary impairment. Furthermore, the strong exposure–response gradient across job sections emphasized the need for administrative interventions, such as rotation of workers between low- and high-dust areas and implementation of wet cleaning methods to minimize airborne fibers (Järvholm and Burdorf 2024) (19). The implications of these findings extend beyond occupational medicine into the public health domain. Textile manufacturing remains a key employment sector in Faisalabad and across Punjab, and chronic respiratory impairment among its workers not only reduces individual quality of life but also contributes to decreased productivity and economic loss. The study reaffirmed the critical importance of instituting routine spirometric surveillance and dust monitoring programs within industrial settings, supported by national-level policy enforcement of occupational safety standards (Krabbe et al. 2024) (20). Despite its strengths, including a well-calculated sample size, standardized spirometric assessment, and objective exposure categorization, several limitations should be acknowledged. The cross-sectional design limited the ability to infer causal relationships, though the consistency of dose–response trends provided strong epidemiological evidence. Ambient dust measurements, while accurate for group-level categorization, did not capture individual exposure variability. The study population consisted predominantly of male workers, reflecting the gender distribution in Faisalabad mills, which may limit generalizability to female workers. Additionally, the study did not measure biochemical or inflammatory biomarkers, which could have provided deeper insight into early subclinical respiratory damage. Nevertheless, the study provided valuable region-specific data from Faisalabad, a major textile hub previously underrepresented in national occupational health literature. Its integration of spirometry with exposure quantification enhanced the reliability of findings, offering a clear epidemiological profile of textile-related pulmonary impairment in the region.

Future research should adopt longitudinal designs to monitor annual changes in spirometric indices among workers, explore biomarker-based mechanisms of dust-induced inflammation, and assess the effectiveness of targeted interventions such as improved ventilation, dust suppression technologies, and protective mask use. Collaboration between occupational health authorities and industry management will be essential to implement feasible preventive measures and to establish a sustainable respiratory health monitoring system in Pakistan's textile sector. Overall, the study contributed meaningful empirical evidence

demonstrating that chronic cotton dust exposure in textile industries remains a significant occupational hazard in Faisalabad. The progressive decline in spirometric parameters and the high symptom burden observed emphasize the urgent need for preventive occupational health reforms and continuous surveillance to protect the respiratory well-being of this large industrial workforce.

CONCLUSION

The study concluded that prolonged exposure to cotton dust in Faisalabad's textile industry significantly impairs lung function, with FEV_1 and FVC declining progressively with higher exposure levels and longer employment duration. Spirometry proved to be an effective tool for early detection of respiratory compromise. These findings highlight the urgent need for routine pulmonary screening, improved ventilation systems, and stricter enforcement of occupational safety regulations to safeguard the respiratory health of textile workers in Pakistan.

AUTHOR's CONTRIBUTION:

Author	Contribution
Farhan Ahmed	Conceptualization, Methodology, Formal Analysis, Writing - Original Draft, Validation, Supervision
Sairah Aslam	Methodology, Investigation, Data Curation, Writing - Review & Editing

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