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INFLUENCE OF AIR POLLUTION ON RESPIRATORY FUNCTION IN URBAN SLUMS: A PHYSIOLOGICAL, COMMUNITY MEDICINE, AND PULMONOLOGICAL PERSPECTIVE

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ABSTRACT

Objective: This study assesses the impact of air pollution on respiratory health among residents of urban slums, analyzing physiological, community medicine, and pulmonological data to elucidate pollution's influence on respiratory function within socioeconomically disadvantaged settings.

Methods: A sample of 200 individuals from urban slums was evaluated through demographic, socioeconomic, and physiological data collection. Pollutant exposure, smoking habits, and respiratory health outcomes were analyzed using spirometry, peak expiratory flow rate (PEF) tests, and blood gas assessments. Demographic data included age, occupation, and education level, while environmental exposure was quantified through PM2.5, PM10, ozone, NO_2, SO_2, and CO measurements.

Results: Participants exhibited high exposure to pollutants, with mean PM2.5 and PM10 levels of 92.8 µg/m³ and 129 µg/m³, respectively. Respiratory symptoms included cough, wheezing, and chest pain, reported by over 25% of participants. Diagnoses revealed asthma (30.5%), bronchitis (24%), and COPD (23%). Spirometry indicated abnormal lung function in 53.5% of individuals, with a mean FEV1 of 2.15 L and FEV1/FVC ratio of 75.4%. High pollutant exposure correlated with symptom deterioration, especially in smokers and overweight individuals.

Conclusion: The findings highlight a critical link between high pollution levels and respiratory impairment in urban slums. Community health interventions focusing on pollution reduction,

respiratory care accessibility, and education are essential for mitigating respiratory health disparities in these high-risk populations.

Keywords: air pollution, respiratory function, urban slums, spirometry, community health, PM2.5, COPD, asthma, smoking.

INTRODUCTION

Urban slums, characterized by overcrowded and substandard living conditions, present an exacerbated public health challenge due to high exposure to air pollution, a major environmental health hazard. The burden of air pollution is disproportionately high in these areas, where limited infrastructure and high vehicular traffic result in increased ambient and indoor pollution levels. Air pollution, particularly in densely populated urban slums, has been shown to adversely impact respiratory function, leading to chronic and acute respiratory illnesses like asthma, chronic obstructive pulmonary disease (COPD), and respiratory infections. This study explores the complex interaction between air pollution and respiratory health, focusing on physiological, pulmonological, and community medicine perspectives to understand and address the adverse effects on residents in urban slums.

The etiology of respiratory diseases in urban slums is multifaceted. Pollution sources in these areas include traffic emissions, industrial pollutants, and household pollutants from biomass combustion, all of which contribute significantly to respiratory ailments. Studies indicate that particulate matter (PM), nitrogen dioxide (NO2), and sulfur dioxide (SO2) are primary pollutants that impair lung function by triggering inflammatory responses and oxidative stress in the respiratory tract (Checkley et al., 2016), (Akhter et al., 2013). In particular, PM2.5 from traffic and industrial activities induces bronchial obstruction and reduces vital lung capacity, often exacerbating pre-existing conditions such as asthma and COPD (Badyda et al., 2013).

Pulmonological studies emphasize the heightened vulnerability of slum dwellers to respiratory diseases due to prolonged exposure to harmful pollutants. Epidemiological evidence reveals that chronic exposure to airborne pollutants in slums is associated with a notable reduction in lung function, with specific impacts on forced expiratory volume (FEV1) and forced vital capacity (FVC) measures. Research demonstrates that both adults and children living in slums exhibit lower lung function metrics compared to non-slum residents, suggesting a cumulative burden of respiratory illness due to continuous pollutant exposure (Ghosh & Mukherji, 2014), (Penttinen et al., 2001).

From a physiological perspective, exposure to pollutants such as SO2 and NO2 has been found to impair mucociliary clearance, which serves as a primary defense mechanism in the respiratory system. The accumulation of pollutants in the airways leads to chronic inflammatory responses, resulting in fibrosis and other lung tissue damages that restrict airflow and degrade respiratory function (Yang & Yang, 1997). Furthermore, pollutants like ozone and particulate matter disrupt normal lung development and function, particularly among children, making them more susceptible to respiratory diseases later in life (Wright & Brunst, 2013).

Community medicine approaches provide essential insights into the public health impact of air pollution in slums, highlighting the socioeconomic and environmental determinants that compound respiratory health risks. Residents in urban slums often face inadequate healthcare access, exacerbating the effects of air pollution as they lack timely diagnosis and treatment for respiratory conditions. Studies suggest that addressing these health inequalities and improving air quality in slum areas could result in significant health gains, reducing the prevalence of respiratory diseases and associated healthcare costs (Arora et al., 2018), (D'Amato et al., 2002). Addressing the pollution-health nexus in slum settings is critical for public health interventions aimed at alleviating the disease burden among vulnerable populations. A review of the literature underscores a strong link between air pollution exposure and respiratory dysfunction in urban slums. For instance, particulate matter and nitrogen dioxide have been associated with reduced lung growth in children and increased respiratory morbidity among adults (Avol et al., 2001), (Dauchet et al., 2018).

Interventions targeting air quality improvements, coupled with access to medical care, are essential to mitigate these health effects.

The aim of this study is to examine the physiological impacts of air pollution on respiratory function in urban slum dwellers from an integrative perspective encompassing pulmonology, physiology, and community medicine. By investigating the mechanisms by which pollutants contribute to respiratory dysfunction, and analyzing community health data, this study aims to provide evidence-based insights into effective public health strategies for respiratory health improvement in urban slums.

METHODS

Research Design

This study employs a cross-sectional observational design to investigate the impact of air pollution on respiratory health among residents of urban slums in Pakistan, integrating perspectives from physiology, community medicine, and pulmonology. The study population includes adult residents aged 18 to 69 from urban slum areas, capturing a diverse demographic representative of high-density, low-income communities. The study design is based on a framework of comparing respiratory function across varied exposure levels to pollutants such as PM2.5, PM10, and nitrogen dioxide (NO2). Environmental and physiological assessments are key components of this research. Data collection includes participant interviews, clinical evaluations, spirometry tests, and laboratory analyses to measure respiratory outcomes. Environmental data on pollutant levels (PM2.5, PM10, NO2, Ozone, SO2, CO) was obtained through field sensors in each selected slum, allowing a detailed account of each participant's exposure level. This research aims to determine the correlation between these pollutants and primary respiratory outcomes such as peak expiratory flow rate (PEF) and forced expiratory volume in one second (FEV1).

Study Participants

The sample consisted of 200 adult residents from selected urban slums across Pakistan, ensuring equal representation of diverse ethnic backgrounds, income levels, and educational backgrounds. Participants were identified through a stratified random sampling approach to maintain representativeness. Demographic data reveals an average participant age of 42.6 years. Participants were categorized based on their exposure level to pollutants, allowing for subgroup analyses on pollutant-specific respiratory impacts. Moreover, the study considered relevant socioeconomic and lifestyle variables such as smoking status, occupation, and family history of respiratory conditions, as these factors may influence respiratory health. The distribution of smoking status indicated.

Inclusion and Exclusion Criteria

Inclusion criteria required participants to be permanent residents of the urban slum area with a minimum of one year of residence, ensuring sufficient exposure to the study area’s air pollution levels. Residents aged 18 to 69 were included to target the adult working-age population most susceptible to pollution-related occupational and environmental health risks. Exclusion criteria involved any participant with a recent history of acute respiratory infections or other significant non-respiratory health conditions that could confound respiratory function tests. Pregnant women and individuals with known congenital respiratory anomalies were also excluded to ensure a homogeneous sample that accurately reflects the urban slum population's adult health status without confounding variables from unrelated health conditions.

Statistical Analysis

Statistical analyses were performed using SPSS software to evaluate differences across exposure levels and to test the significance of pollutant impacts on respiratory function. Descriptive statistics (mean, median, range, and percentiles) were computed for continuous variables, including age, BMI, residence duration, PEF, and FEV1. For categorical data (such as gender, ethnicity, education level, smoking status, and family history of respiratory conditions), frequency distributions and chi-square

tests assessed differences across groups. To examine the correlation between pollutant exposure and respiratory function, Mann-Whitney U tests were used to compare continuous respiratory function measures (FEV1, FEV1/FVC ratio, PEF) across categories of spirometry results (normal vs. abnormal). Nonparametric chi-square tests assessed the distribution of categorical variables such as respiratory symptoms, diagnosis, and treatment outcomes across different levels of pollutant exposure.

RESULTS

The study involved a sample of 200 participants, comprising 49.5% females and 50.5% males, illustrating a balanced gender distribution. The population was ethnically diverse, with representation from Balochi (25.5%), Pathan (22.5%), Punjabi (23%), and Sindhi (29%) groups, reflecting the typical demographic makeup of urban slum areas. The average age of participants was 42.6 years, with ages ranging from 18 to 69, indicating a primarily adult demographic that has experienced extended exposure to environmental pollutants. Income levels varied, with 36.5% classified as high-income, 34.5% as middle-income, and 29% as low-income. These income categories correspond with educational levels, as a considerable number of participants had only primary education or no formal education at all (27.5% and 23.5%, respectively). The majority of participants were engaged in occupations such as laborers (30.5%), vendors (25%), and the unemployed (24.5%), all of which entail significant outdoor exposure. Such working conditions may heighten the risk of exposure to air pollution, potentially leading to negative respiratory health outcomes.

Table 1: Demographics and Socioeconomic Context in Urban Slum Populations.

Attribute	Category	Frequency	Percentage
Age	Mean	42.61	-
Gender	Female	99	49.5%
	Male	101	50.5%
Ethnicity	Balochi	51	25.5%
	Pathan	45	22.5%
	Punjabi	46	23.0%
	Sindhi	58	29.0%
Income Level	High	73	36.5%
	Low	58	29.0%
	Middle	69	34.5%
Education Level	None	47	23.5%
	Primary	55	27.5%
	Secondary	43	21.5%
	Tertiary	55	27.5%
Occupation	Laborer	61	30.5%
	Service	40	20.0%
	Unemployed	49	24.5%
	Vendor	50	25.0%

Air quality assessments indicate significant exposure to fine particulate matter (PM2.5), with an average concentration of 92.8 µg/m³, which greatly exceeds the guidelines set by the World Health Organization. PM10 levels were recorded at an average of 129 µg/m³, further underscoring the high pollutant levels in these areas. Additional pollutants, such as ozone (mean 43.4 µg/m³), nitrogen dioxide (NO_2, 58.7 µg/m³), sulfur dioxide (SO_2, 27.7 µg/m³), and carbon monoxide (CO, 4.68 µg/m³), were also found at concerning concentrations. The distribution of these pollutants indicates that elevated levels of PM2.5 and PM10 are persistent, with upper quartiles reaching 122 µg/m³ and

170 µg/m³, respectively. These pollutant concentrations are linked to reported health symptoms and diagnostic findings, demonstrating a clear relationship between air pollution exposure and respiratory health issues. Approximately 32.5% of participants indicated high exposure to air pollution, while 30.5% reported moderate exposure. High levels of exposure have been associated with increased rates of respiratory problems. The most common respiratory issues reported included chest pain (27%), cough (26.5%), wheezing (25.5%), and breathlessness (21%). These symptoms are consistent with established research on the adverse health effects of long-term exposure to urban pollutants, which are known to worsen respiratory conditions.

Table 2: Exposure Levels to Air Pollutants and Associated Health Status Indicators.

Pollutant	Min	Max	Mean	Standard Deviation
PM2.5 (µg/m³)	35.09	149.44	92.81	26.57
PM10 (µg/m³)	50.28	199.77	129.04	35.22
Ozone (ppb)	10.3	80.0	43.37	14.78
NO2 (ppb)	20.1	98.7	58.74	17.86
SO2 (ppb)	5.2	50.0	27.73	11.21
CO (ppm)	0.6	9.9	4.68	2.41

The research revealed a nearly balanced occurrence of acute (50.5%) and chronic (49.5%) respiratory symptoms among the participants, highlighting the existence of both immediate and persistent respiratory challenges within this group. Diagnoses included asthma (30.5%), bronchitis (24%), chronic obstructive pulmonary disease (COPD, 23%), while a smaller segment was classified as healthy (22.5%). The elevated rates of asthma and bronchitis correspond with the presence of pollutants like PM2.5 and NO_2, which are recognized for their role in irritating respiratory pathways and contributing to chronic conditions over time. Spirometry assessments showed that 53.5% of participants exhibited abnormal lung function, underscoring significant respiratory impairment in this population. The average forced expiratory volume in one second (FEV1) was recorded at 2.15 L, with an FEV1/FVC (forced vital capacity) ratio of 75.4%, indicating potential restrictive lung diseases. Additionally, the reduced peak expiratory flow (PEF) rates, averaging 452.2 L/min and dipping to a minimum of 202.8 L/min, further support these observations, suggesting obstructive patterns linked to airway resistance from pollution exposure.

Table 3: Respiratory Symptoms and Diagnostic Data Across Sampled Population.

Parameter	Min	Max	Mean	25th Percentile	Median	75th Percentile
FEV1 (L)	0.87	3.49	2.15	1.51	2.12	2.75
FEV1/FVC (%)	50.1	100.0	75.37	62.13	75.00	88.08
Peak Expiratory Flow (L)	202.8	697.4	452.19	314.10	452.35	595.33
Chest X-ray Findings	Normal	Abnormal	-	-	-	-
Blood Gases	Normal	Abnormal	-	-	-	-
Allergen Test	Neg	Pos	-	-	-	-

Elevated levels of pollutants have been consistently associated with the worsening of respiratory symptoms, as demonstrated by both primary and secondary outcomes in this research. The primary outcomes indicate that 28.5% of participants experienced a decline in their health over time, while 36% maintained stable conditions, and only 35.5% reported an improvement. Secondary outcomes further illustrate a continuous rise in symptoms for 31.5% of participants, suggesting ongoing exposure and its harmful impact on lung function. Blood gas analyses reveal that 35.5% of

participants showed signs of hypercapnia, and 32% exhibited hypoxemia, reinforcing the connection between pollution exposure and impaired respiratory function. The observed issues with oxygenation and increased carbon dioxide levels in the blood point to compromised pulmonary function, especially in individuals with pre-existing respiratory issues. Furthermore, allergen testing revealed a positive rate of 47.5%, indicating environmental sensitivities that may worsen asthma and other respiratory ailments.

Table 4: Environmental Pollutants and Health Impact Correlations in Urban Slums.

Environmental Factor	Spirometry Abnormal (%)	Respiratory Symptoms (%)	Diagnosed with Respiratory Illness (%)
High PM2.5	53.5	60.5	55.0
High PM10	51.5	58.0	52.0
High NO2	52.0	61.0	54.5
High SO2	50.5	59.5	53.0

Smoking status is a significant factor in respiratory health, with 30% of participants identified as current smokers and an additional 30% as former smokers.

Table 5: Influence of Smoking and Lifestyle Factors on Respiratory Health.

Lifestyle Factor	Category	Frequency	Percentage
Smoking Status	Current Smoker	60	30.0%
	Former Smoker	60	30.0%
	Non-Smoker	80	40.0%
Residence Duration	Mean (years)	-	19.63
Family History	Yes	96	48.0%
	No	104	52.0%

When combined with high levels of environmental pollutants, smoking is likely to worsen respiratory problems. Individuals with a smoking history who are exposed to pollutants such as nitrogen dioxide (NO_2) and particulate matter (PM10) may experience a quicker progression of conditions like chronic obstructive pulmonary disease (COPD), leading to more intense symptoms and a more rapid deterioration of lung function.

Table 6: Impact of Primary Health Conditions on Respiratory Functionality.

Intervention Type	Population Group	Improvement (%)	No Change (%)	Deterioration (%)
Antibiotics	High Risk	40.0%	35.0%	25.0%
Inhalers	Moderate Risk	45.5%	32.0%	22.5%
Nebulization	Low Risk	50.0%	30.5%	19.5%
Oxygen Therapy	High Risk	55.0%	30.0%	15.0%

Respiratory health outcomes are closely linked to body mass index (BMI), with an average BMI of 26.9 kg/m² indicating a trend towards overweight within the population. Obesity is recognized as a factor that exacerbates respiratory issues, and when coupled with high levels of pollutant exposure, it can lead to diminished pulmonary function due to increased airway resistance.

The combination of elevated BMI, exposure to pollutants, and a history of smoking points to a complex interplay of factors contributing to respiratory distress in this demographic. These findings highlight an urgent need for community health initiatives that address pollution control and individual risk factors, particularly in urban slum areas. There is a pressing requirement for medical

interventions aimed at improving access to respiratory healthcare, especially for the 36.5% of the sample identified as high-risk. The significant demand for nebulization or oxygen therapy, reported at 34%, underscores the necessity for facilities dedicated to chronic respiratory care. Additionally, tailored strategies for the population should include the establishment of mobile healthcare units and community clinics to facilitate early diagnosis and management of respiratory diseases in these communities.

DISCUSSION

The study highlights that high exposure to pollution is associated with respiratory dysfunction among residents in urban slums. In the demographic analysis, the majority of the subjects were of working age, with a mean age of 42.6 years, involved in outdoor occupations, which enhanced daily exposure to pollutants. The environmental data showed high PM2.5 and PM10 levels, with high NO_2, SO_2, and CO concentrations above WHO-recommended threshold levels. These high levels of exposure correspond directly to the presence of respiratory impairments, abnormal spirometry results in 53.5% of the participants, and a high incidence of respiratory diseases like asthma and bronchitis, 30.5% and 24%, respectively. This study is important in underlining the severe health repercussions due to pollutant exposure in an urban slum environment (Penttinen et al., 2001). Therefore, high values of particulate matter, especially PM2.5 and PM10, added to occupational and lifestyle factors such as smoking, greatly increase the risk for developing chronic respiratory ailments. Indeed, abnormal patterns of lung function were observed among well over half the participants (Sancini et al., 2010). The abnormal pattern of lung function included both restrictive and obstructive pulmonary patterns, which have been more highly associated with high levels of exposure to pollutants. Results of this magnitude therefore carry immense importance for public health policy and healthcare delivery in crowded and poor urban settings (Seaton et al., 1995).

The present study coincides with previous literature on the effects of air pollutants on respiratory health in low-income urban areas (Turnovska & Marinov, 2009). Indeed, similar studies show that due to proximity to traffic and industrial pollutants, slum dwellers have a higher incidence of asthma, COPD, and respiratory infections (van der Zee et al., 2000). The measured rates of PEF and the volumes of forced expiration from our sample are comparable to those populations known for chronic pollutant exposure, thus standing consistent with the reported cases of impairment of lung function due to environmental pollutants. This study calls for urgent need in targeted community health interventions. The strategies for reduction of exposure to pollution at the local level include restriction of industrial emissions in residential zones and also dissemination of public awareness regarding the health hazards from pollution. Medical interventions are required to facilitate improved access to respiratory health care, especially for those already afflicted with certain conditions (Wright & Brunst, 2013). Mobile health units or local clinics can be provided for early detection and management of respiratory diseases, which would be of considerable benefit to this population (Yang & Yang, 1997). Public health initiatives may also wish to target smoking cessation programs, as smoking rates remain high and contribute to respiratory health. The limitations of this study are that this was a cross-sectional study; therefore, any causality cannot be established. Symptoms and lifestyle factors, such as smoking status, were self-reported, and there is a risk of biased data. The second issue at play is the longitudinal data on limits of pollutant exposure, understanding of long-term health outcomes, and disease progression. Finally, the respiratory health assessment may not be as thorough as it should be if there is no easy access to advanced diagnostic equipment in urban slums.

Future studies should be designed longitudinally, as a longitudinal design will be far better to monitor the progression of respiratory impairments in response to pollutant exposure over time. Further research into the interaction of specific occupational exposures with pollutant types might give further detail on risk factors in the slum environment. Therefore, generalization might be facilitated by expanding the current study to other urban slums within different geographical regions. This can enable regional differences in pollutant types and levels of exposure. Future studies could

also explore the ways that dietary or other modifiable lifestyle factors can be leveraged to offset pollution-related health impacts in resource-poor settings.

CONCLUSION

This study shows that air pollution has a high impact on respiratory health among urban slum dwellers, whose pre-existing socio-economic adversities are aggravated by high levels of pollutants like PM2.5, NO_2, and SO_2. Respiratory symptoms, abnormal spirometry findings, and chronic respiratory disorders such as asthma and bronchitis prevail at a high level among the residents. The results show that respiratory health deteriorates due to contribution from the environment and lifestyle factors, such as smoking and inadequate health access. These are the foci of community health efforts, pollution abatement, and increased access to health care, which would greatly ameliorate respiratory health outcomes in these densely settled regions.

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