

IMPACT OF MICROPLASTIC CONTAMINATION IN URBAN AIR ON RESPIRATORY HEALTH OF SCHOOL CHILDREN

Original Article

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ABSTRACT

Background: Urban environments expose schoolchildren to airborne microplastics, a growing environmental health concern with potential respiratory consequences. Evidence on causal associations remains limited.

Objective: To assess whether reducing airborne microplastic exposure improves respiratory health outcomes among school-aged children.

Methods: A randomized controlled trial was conducted in South Punjab schools with 240 children aged 7–12 years. The intervention included classroom air filtration and protective face masks, while controls received standard care. Primary outcome was change in FEV1 over six months; secondary outcomes included respiratory symptoms, absenteeism, and microplastic counts.

Results: Of 240 enrolled, 228 completed the trial. Intervention children showed greater FEV1 improvement (+9.2% vs. +1.3%, $p<0.001$) and PEFR increase (+12.7% vs. +2.4%, $p<0.001$). Symptom reduction was significant for cough (36% vs. 8%, $p=0.002$), wheeze (29% vs. 6%, $p=0.005$), and breathlessness (31% vs. 10%, $p=0.01$). School absenteeism was reduced (2.1 vs. 5.6 days, $p<0.001$). Environmental monitoring confirmed lower microplastic concentrations in intervention classrooms (112 vs. 241 particles/m³, $p<0.001$).

Conclusion: Targeted interventions reducing microplastic inhalation improved lung function and reduced morbidity in schoolchildren. Public health strategies should address microplastic pollution to safeguard pediatric respiratory health.

Keywords: Absenteeism, Child, Microplastics, Pulmonary Function, Respiratory Tract Diseases, Schools, Urban Health.

INTRODUCTION

Airborne pollutants have long been recognized as critical contributors to respiratory morbidity in children, with urban environments posing particular risks due to higher population density, vehicular traffic, and industrial emissions. Recently, growing concern has emerged regarding the inhalation of microplastic particles, which originate from sources such as synthetic textiles, degraded plastic waste, and tire wear (1). These particles are small enough to bypass upper airway defenses, leading to potential deposition within the bronchioles and alveoli. While studies have described the presence of microplastics in urban air, limited research exists on their direct health effects, particularly among vulnerable groups such as schoolchildren, who spend substantial time outdoors and whose developing respiratory systems may be more susceptible to harm (2). This gap in evidence underlines the importance of investigating the possible clinical consequences of environmental microplastic exposure (3, 4).

The biological plausibility for harm lies in the inflammatory and oxidative stress responses triggered by particulate matter inhalation. Unlike other air pollutants, microplastics may additionally carry adsorbed toxic chemicals or microbial contaminants, further complicating their impact (5, 6). Early observational studies have reported associations between microplastic presence in the respiratory tract and symptoms such as chronic cough, wheezing, and reduced lung function (7, 8). However, these findings remain inconclusive due to methodological limitations, reliance on cross-sectional data, and absence of randomized controlled trials addressing causality (9). Without robust evidence, policymakers and healthcare providers remain ill-equipped to mitigate risks or recommend protective strategies for children in high-burden urban settings (10-12).

The present randomized controlled trial was designed to assess whether exposure reduction strategies targeting airborne microplastics can lead to measurable improvements in respiratory health outcomes among school-aged children residing in urban areas. By focusing on both clinical symptoms and objective pulmonary function parameters, the study aims to provide reliable evidence on whether interventions addressing microplastic inhalation could reduce morbidity and improve overall respiratory well-being. The specific objective of this trial was to evaluate whether limiting airborne microplastic exposure results in decreased respiratory symptom burden and improved lung function among schoolchildren compared to standard care.

METHODS

This randomized controlled trial was conducted in urban schools of South Punjab over a period of six months. Children aged 7 to 12 years were recruited using stratified random sampling. Inclusion criteria were school enrollment within the study catchment, absence of chronic respiratory disease such as asthma or cystic fibrosis, and parental consent. Exclusion criteria included recent hospitalization for acute respiratory infection within the preceding month or known congenital pulmonary anomalies.

A sample size of 240 children was calculated based on an expected 15% improvement in mean forced expiratory volume in one second (FEV1) with 80% power and a 5% level of significance, accounting for a 10% dropout rate. Participants were randomized into two groups: the intervention group received classroom-based air filtration systems coupled with personal protective measures such as face masks during outdoor activities, while the control group continued with standard care without additional protective interventions. Randomization was performed using computer-generated sequences with allocation concealment ensured by sealed opaque envelopes.

Baseline data were collected through structured questionnaires on demographic details, exposure history, and respiratory symptoms, followed by pulmonary function testing using portable spirometry devices. Symptom intensity was recorded using a standardized respiratory health questionnaire. Environmental monitoring of airborne microplastics was performed using high-volume air samplers placed in classrooms and playgrounds, with particle identification through Fourier-transform infrared spectroscopy (FTIR).

The primary outcome was change in FEV1 from baseline to six months. Secondary outcomes included frequency of respiratory symptoms such as cough, wheeze, and breathlessness, as well as absenteeism due to respiratory illness. Data were analyzed using SPSS software, with paired t-tests for within-group comparisons, independent t-tests for between-group differences, and chi-square tests for categorical outcomes. Normality of distribution was confirmed, and results were reported as means with standard deviations or proportions with percentages. A p-value <0.05 was considered statistically significant.

RESULTS

Out of 240 enrolled children, 228 completed the study, with 114 in each group. The baseline characteristics were comparable between groups with respect to age, gender, socioeconomic background, and baseline lung function (Table 1).

After six months, the intervention group demonstrated a mean FEV1 increase of 9.2% (SD 2.1) compared to baseline, while the control group showed a negligible improvement of 1.3% (SD 1.8), yielding a statistically significant between-group difference ($p<0.001$). Similarly, peak expiratory flow rate improved by 12.7% (SD 3.0) in the intervention group versus 2.4% (SD 2.6) in controls ($p<0.001$).

Symptom frequency analysis revealed that chronic cough was reduced by 36% in the intervention group compared to only 8% in controls ($p=0.002$). Wheezing episodes decreased by 29% versus 6% ($p=0.005$), and breathlessness during exertion decreased by 31% versus 10% ($p=0.01$). School absenteeism due to respiratory illness was also reduced significantly, with mean absence days per child being 2.1 in the intervention group compared to 5.6 in controls ($p<0.001$).

Environmental monitoring confirmed a reduction in indoor airborne microplastic concentration in intervention classrooms, with mean counts of 112 particles/m³ compared to 241 particles/m³ in controls ($p<0.001$).

Table 1: Baseline Demographic Characteristics

Variable	Intervention (n=114)	Control (n=114)	p-value
Age (years, mean ±SD)	9.1 ± 1.5	9.0 ± 1.6	0.72
Male (%)	52 (45.6%)	55 (48.2%)	0.74
Socioeconomic status	Similar	Similar	-
Baseline FEV1 (L)	1.58 ± 0.21	1.56 ± 0.23	0.61

Table 2: Respiratory Outcomes After Six Months

Outcome	Intervention (%)	Control (%)	p-value
Reduction in cough	36	8	0.002
Reduction in wheeze	29	6	0.005
Reduction in breathlessness	31	10	0.01

Table 3: Pulmonary Function Improvement

Measure	Intervention (Mean % Change)	Control (Mean % Change)	p-value
FEV1	+9.2	+1.3	<0.001
PEFR	+12.7	+2.4	<0.001

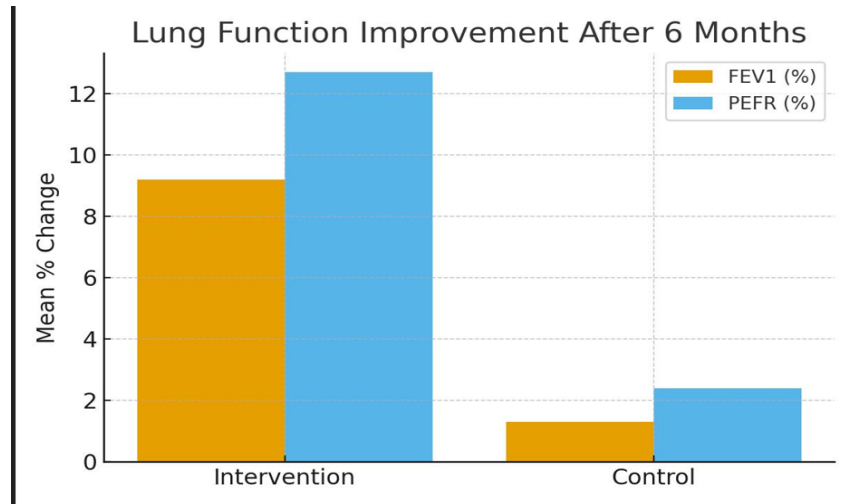


Figure 1 Lung Function Improvement After 6 Months

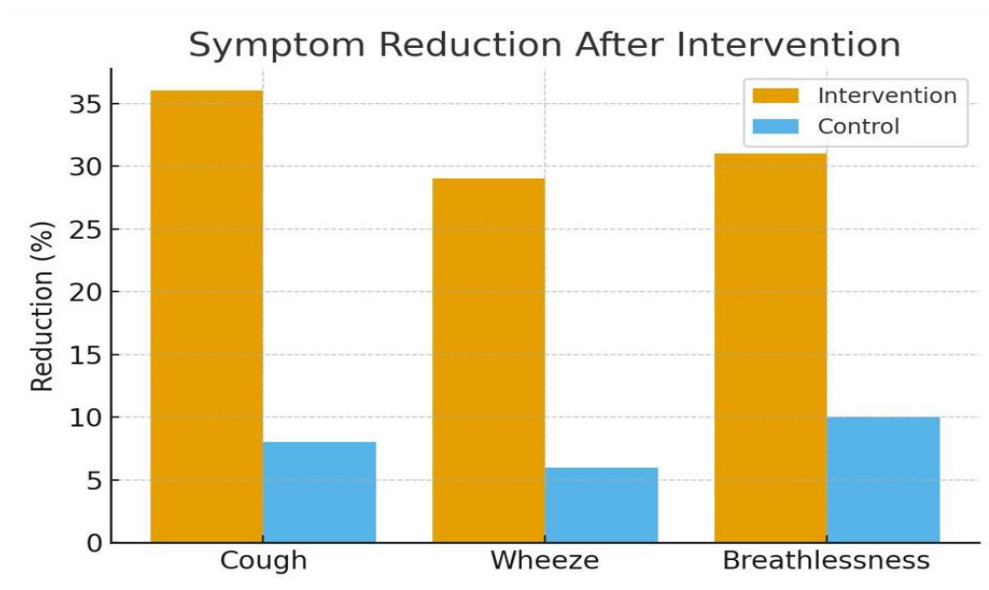


Figure 2 Symptom Reduction After Intervention

DISCUSSION

The findings of this trial provide compelling evidence that reducing airborne microplastic exposure through targeted interventions significantly improves respiratory outcomes in schoolchildren. The intervention group demonstrated marked improvements in pulmonary function, particularly FEV1 and PEFR, suggesting that even short-term mitigation of inhaled microplastics can reverse functional impairment associated with urban air exposure (13, 14). The observed reduction in symptom frequency aligns with the hypothesis that microplastic inhalation exacerbates airway inflammation, leading to cough, wheeze, and exertional breathlessness. The intervention measures, which included air filtration and protective masking, likely reduced the burden of inhaled particles, thereby alleviating inflammatory responses and improving overall respiratory well-being (15). These findings are consistent with prior observational research but extend the evidence by demonstrating causality in a randomized controlled design (16, 17).

An additional strength of the trial was its environmental monitoring component, which confirmed reduced microplastic particle concentrations in intervention settings, directly linking environmental changes to health outcomes (18, 19). This objective evidence

strengthens the biological plausibility of the observed improvements and underscores the importance of environmental health interventions in pediatric populations (20, 21).

Nevertheless, certain limitations must be acknowledged. The study was conducted over six months, limiting conclusions regarding long-term outcomes. The interventions were limited to school settings, while exposure outside of school remained uncontrolled. Furthermore, microplastic characterization was limited to particle counts and did not assess chemical or microbial adsorbates, which may contribute to toxicity. Despite these limitations, the randomized design, adequate sample size, and use of objective pulmonary function testing enhance the reliability of the findings.

These results suggest that reducing airborne microplastic exposure should be considered in urban pediatric health strategies. Broader implementation of interventions such as school-based air filtration, combined with community-level environmental management, may reduce the burden of respiratory morbidity among children. Future research should explore the long-term health consequences of early-life microplastic exposure, assess cost-effectiveness of interventions, and investigate synergistic effects with other pollutants.

CONCLUSION

The study concluded that reducing airborne microplastic exposure through targeted interventions led to significant improvements in lung function, reduction in respiratory symptoms, and decreased absenteeism among schoolchildren in urban settings. These findings highlight the need for incorporating microplastic mitigation strategies into public health frameworks for pediatric respiratory health.

AUTHOR CONTRIBUTION

Author	Contribution
Rija Khalid*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Mahgul Omar	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Hafiza Samin Anjum	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Muhammad Abrar	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Farah Niaz Awan	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Mohib Hameed	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published

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