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Bhimanagouda Basanagoudar
JSS Academy of Higher Education and Research
SHILPA D M
shilpadm@jssuni.edu.in

JSS Academy of Higher Education and Research
MANJUNATH M C
JSS Medical College and Hospital

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Association Between Ambient and Indoor Air Pollution Exposure and Nutritional Status of Under-5 (36–59 Months) Children: An Analytical Cross-Sectional Study in Mysuru, India

Bhimanagouda S. Basanagoudar[1], D. M. Shilpa[1]* Manjunath M C[2]

[1] School of Public Health, JSS Medical College, JSS Academy of Higher Education & Research, Mysuru – 570015, Karnataka, India

[2]Department of Community Medicine, JSS Medical College, JSS Academy of Higher Education and Research, Mysuru, Karnataka, India

***Corresponding author:** Dr. D. M. Shilpa | Email: shilpadm@jssuni.edu.in | School of Public Health, JSS Medical College, JSS AHER, Mysuru – 570015

Abstract

Background: Childhood undernutrition and air pollution are converging crises in low- and middle-income countries. Despite a well-established biological rationale, evidence directly linking measured air pollution exposure to anthropometric nutritional outcomes among young children remains sparse in the Indian context, particularly in secondary cities such as Mysuru. Urbanisation, biomass combustion for cooking, vehicular emissions, and construction activity collectively drive high particulate matter concentrations, while simultaneously concentrating economically disadvantaged populations who bear the greatest nutritional burdens.

Objectives: To assess ambient and indoor air pollution levels in households of children aged 36–59 months in Mysuru Taluk; to estimate the prevalence of undernutrition (stunting, wasting, and underweight); and to determine the association between air pollution exposure and anthropometric nutritional outcomes.

Methods: An analytical cross-sectional study was conducted among 400 children aged 36–59 months residing in urban and rural areas of Mysuru Taluk using stratified random sampling. Ambient and indoor $PM_{2.5}$ and PM_1 levels were measured using validated portable AQI monitoring devices. Anthropometric measurements (height, weight) were obtained following WHO standard procedures, and nutritional status was assessed using WHO growth standards. Dietary intake was collected using a Food Frequency Questionnaire administered to primary caregivers. Data were analysed using descriptive statistics and Chi-square tests.

Results: Indoor $PM_{2.5}$ exposure was significantly associated with stunting ($\chi^2 = 49.486$, $p = 0.002$) and wasting ($\chi^2 = 49.137$, $p = 0.015$). Indoor AQI categories were significantly associated with wasting ($\chi^2 = 44.903$, $p = 0.039$). Outdoor $PM_{2.5}$ exposure showed a significant association with wasting ($\chi^2 = 36.958$, $p = 0.044$). No statistically significant associations were observed between outdoor air pollution and stunting ($p > 0.05$) or between indoor AQI and underweight status ($p = 0.786$).

Conclusions: Indoor air pollution, particularly elevated $PM_{2.5}$ concentrations, is significantly associated with adverse nutritional outcomes among children aged 36–59 months in Mysuru Taluk. These findings underscore the importance of integrating household air pollution reduction into child nutrition programmes and urban public health policy.

Keywords: air pollution; $PM_{2.5}$; indoor air pollution; ambient air pollution; stunting; wasting; underweight; undernutrition; children under five; Mysuru; India; cross-sectional study

Background

Every year, more than seven million children under the age of five die from preventable causes, a large proportion of which are either directly linked to or substantially aggravated by malnutrition. Over the past two decades, a growing body of epidemiological evidence has illuminated an underappreciated dimension of this crisis: the air that children breathe may be just as consequential for their growth and nutritional development as the food they eat [1].

Air pollution is recognised by the World Health Organisation (WHO) as one of the foremost environmental threats to human health globally. In 2019, ambient air pollution was responsible for an estimated 4.2 million premature deaths, while household air pollution — primarily from cooking with solid biomass fuels — accounted for an additional 3.8 million deaths annually [2]. Children under five are disproportionately vulnerable to both forms of pollution: they breathe more air per unit of body weight than adults, their respiratory and immune systems are still developing, and they typically spend large portions of the day in indoor environments where cooking-related pollution is highest.

India has the highest number of undernourished children in the world. The Fifth National Family Health Survey (NFHS-5, 2019–21) reports that 35.5% of children under five in India are stunted, 19.3% are wasted, and 32.1% are underweight [4]. District-level NFHS-5 data indicate stunting at

approximately 35% in Mysuru district, 20% for wasting, and 33% for underweight. These figures persist despite decades of nutritional programming through the Integrated Child Development Services (ICDS), strongly suggesting that factors beyond diet and poverty alone are driving this burden.

Household air pollution resulting from the combustion of biomass fuels has been associated with several adverse health outcomes in India, including respiratory infections, chronic respiratory diseases, and tuberculosis. Biomass fuel combustion generates high concentrations of particulate matter and other pollutants that may contribute to systemic inflammation and poor child health outcomes [5].

Despite this convergence of high pollution burden and high prevalence of undernutrition in Mysuru and similar Indian secondary cities, rigorous epidemiological studies that directly examine the statistical association between measured air pollution exposure and anthropometric outcomes at the community level remain sparse. Most existing Indian research has relied on national survey data and ecological correlations, or has focused on air pollution's respiratory health effects without linking exposures to nutritional status. The present study addresses this gap directly, generating locality-specific, measurement-based evidence on the relationship between ambient and indoor air pollution exposure and stunting, wasting, and underweight among children aged 36–59 months in Mysuru Taluk.

Objectives

Objective 1: To assess ambient and indoor air pollution levels in the households of children aged 36–59 months in Mysuru Taluk.

Objective 2: To estimate the prevalence of undernutrition (stunting, wasting, and underweight) among children aged 36–59 months in Mysuru Taluk.

Objective 3: To determine the association between ambient air pollution exposure and nutritional outcomes (stunting, wasting, underweight) in children aged 36–59 months.

Objective 4: To determine the relationship between indoor air pollution exposure indicators and undernutrition in children aged 36–59 months.

Methods

Study Design and Setting

An analytical cross-sectional study was conducted across urban and rural areas of Mysuru Taluk, Karnataka, India, between January 2025 and December 2025. Mysuru Taluk encompasses both the Mysuru City Corporation (MCC) urban areas and rural communities, creating the environmental variability necessary to examine differential air pollution exposure and its nutritional consequences.

Study Population and Eligibility

The target population comprised all children aged 36–59 months who were permanent residents of selected households within Mysuru Taluk. Children were eligible if they had resided in their current household for at least three months before enrolment and were available for anthropometric measurement. Exclusion criteria included children with known severe congenital anomalies affecting growth, acute severe illness requiring hospital admission at the time of enrolment, or whose primary caregiver was unable to provide informed consent.

Sample Size

Sample size was calculated using G*Power software informed by the prevalence of stunting reported in comparable Indian urban-rural settings (approximately 35%). With a 5% significance level, 80% power, and an expected 10% nonresponse rate, the minimum required sample size was 360 children. A final target of 400 participants was set to ensure adequate subgroup analyses.

Sampling Strategy

A stratified random sampling approach was employed. All eligible ICDS (Anganwadi) centre areas within Mysuru Taluk were stratified by residential type (urban, rural), and a list of registered under-five children was obtained with ASHA support. Systematic random sampling was applied within each stratum to select households, and within each household, the eligible child closest in age to the index visit date was enrolled. Mini-Nutritional screening was performed at the outset of each visit; children meeting exclusion criteria were not enrolled.

Data Collection Instruments

The following validated instruments were used for data collection:

Table 1. Data collection instruments used are summarized in the study.

Instrument	Purpose / Domains	Source / Validation
Sociodemographic questionnaire	Age, sex, education, SES (BG Prasad), cooking fuel type, housing type, chronic disease, family type	Investigator-developed; pilot-tested on 30 participants
Air Pollution Measurement (AQI Monitor)	Ambient and indoor $PM_{2.5}$ and PM_{1} levels measured at the household level using validated portable AQI devices (24-hour mean)	Calibrated AQI monitors; WHO/NAAQ reference standards
Food Frequency Questionnaire (FFQ)	Dietary diversity, food group consumption frequency, micronutrient intake adequacy	Adapted from ICDS-validated FFQ; caregiver-administered
Anthropometric Measurements	Height (HAZ/stunting), Weight (WAZ/underweight), Weight-for-height (WHZ/wasting)	WHO Growth Standards (2006); Anthro software
Mini Nutritional Assessment (Caregiver)	Caregiving quality, breastfeeding history, and complementary feeding practices	Structured caregiver interview form

Data Collection Procedure

Data were collected through face-to-face interviewer-administered questionnaires and direct measurements at participants' households over twelve months. Air quality monitoring devices were placed in the principal cooking area, bedroom, hall, and the immediate outdoor vicinity of the household for a 24-hour monitoring period. Anthropometric measurements (height and weight measured) were performed following the WHO standard procedures. All children were measured in light clothing and without footwear. Z-scores were calculated using the WHO Anthro software.

Ethical Considerations

Ethical clearance was obtained from the Institutional Ethics Committee of JSS Academy of Higher Education and Research, Mysuru. Written informed consent was obtained from the primary caregiver of all participant children before enrolment. Participation was entirely voluntary, and caregivers were free to withdraw at any time without consequence. All data were anonymised and stored securely.

Statistical Analysis

Data were entered in MS Excel and analysed using IBM SPSS version 30. Categorical variables were described as frequencies and percentages; continuous variables as means and standard deviations. $PM_{2.5}$ and AQI values were categorised using the US EPA AQI standard breakpoints. Anthropometric Z-scores were categorised according to WHO growth standards: stunting (HAZ < −2 SD), wasting (WHZ < −2 SD), and underweight (WAZ < −2 SD). Chi-square tests were used to examine associations between air pollution exposure categories and nutritional outcomes. Statistical significance was set at $p < 0.05$.

Results

A total of 400 children aged 36–59 months were enrolled from urban and rural households of Mysuru Taluk. The following sections present findings from air pollution monitoring, sociodemographic profiling, nutritional status assessment, and association analyses.

Air Pollution Levels and Exposure Distribution

Ambient $PM_{2.5}$ monitoring revealed that 40.5% of households were in the 'unhealthy for sensitive groups' category (35.5–55.4 µg/m³) and 20.8% were in the 'unhealthy' category (≥55.5 µg/m³). Indoor air pollution levels were markedly higher: 40.5% of households recorded indoor $PM_{2.5}$ in the 'unhealthy' category. Among households using biomass fuels exclusively (34.8%), mean indoor $PM_{2.5}$ concentrations during cooking periods exceeded 250 µg/m³ — over 50 times the WHO daily mean guideline of 5 µg/m³.

Table 2. Distribution of air pollution exposure categories among study households (N = 400).

Variable	Category	n	%
Ambient $PM_{2.5}$ exposure category	Good (≤12 µg/m³)	38	9.5
	Moderate (12.1–35.4 µg/m³)	117	29.3
	Unhealthy for sensitive groups (35.5–55.4 µg/m³)	162	40.5
	Unhealthy (≥55.5 µg/m³)	83	20.8

Variable	Category	n	%
Indoor $PM_{2.5}$ exposure category	Good (≤12 µg/m³)	21	5.3
	Moderate (12.1–35.4 µg/m³)	74	18.5
	Unhealthy for sensitive groups (35.5–55.4 µg/m³)	143	35.8
	Unhealthy (≥55.5 µg/m³)	162	40.5
Cooking fuel type	LPG only	142	35.5
	Mixed (LPG + biomass)	119	29.8
	Biomass only	139	34.8
Total		400	100.0

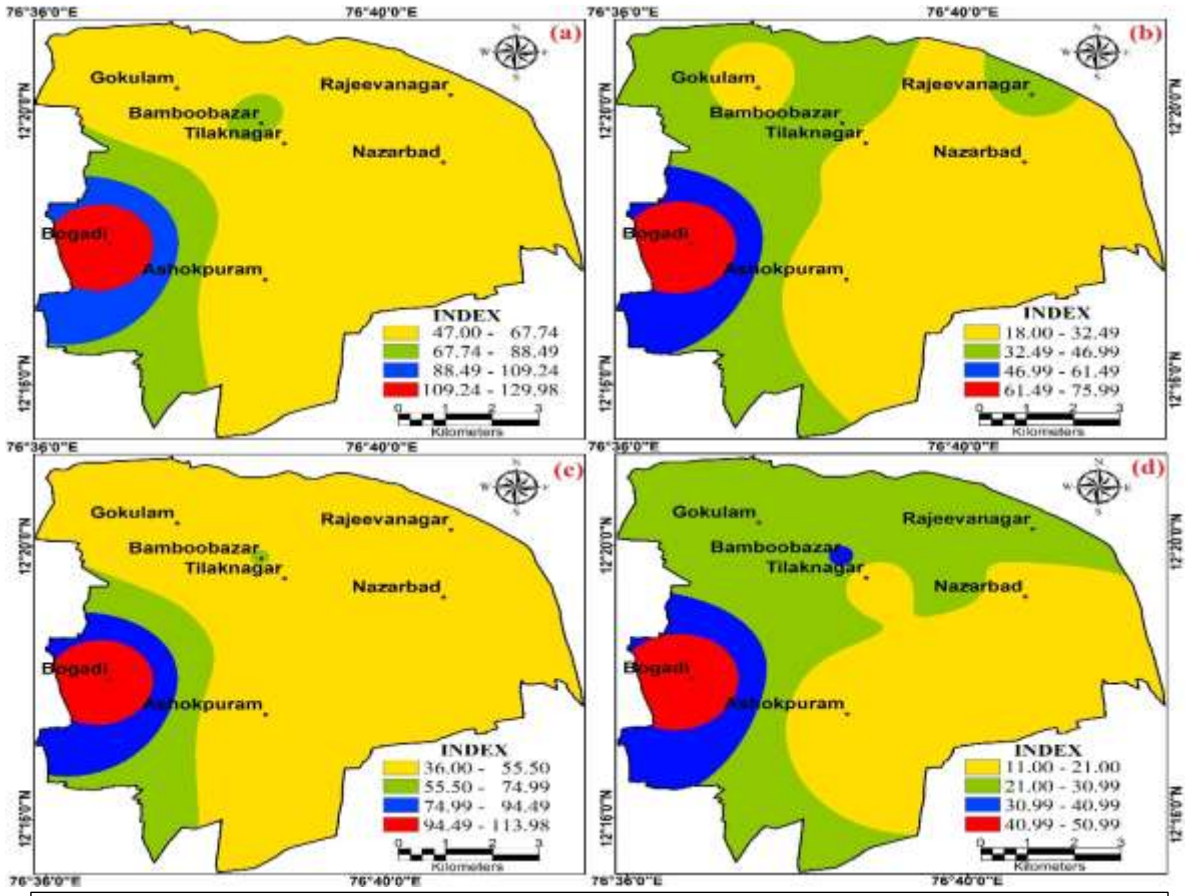
Figure 1. The spatial distribution of air pollution concentrations across Mysuru city is shown.



Fig 1. GIS map for air pollution concentrations across Mysuru city

The spatial interpolation maps generated using GIS techniques indicate considerable spatial heterogeneity in urban air pollutant concentrations across Mysuru city. Among the monitored locations, Bogadi consistently exhibited the highest concentration levels, forming a distinct pollution hotspot in all interpolated surfaces. Concentrations decreased progressively from the western region toward the central and eastern parts of the city. Ashokpuram showed moderate-to-high concentrations, whereas Rajeevanagar, Nazarbad, and Gokulam predominantly recorded lower pollutant levels. The observed spatial pattern suggests the influence of localized anthropogenic emission sources, including vehicular traffic, commercial activities, and road dust, particularly in the western urban corridor. The results highlight the usefulness of GIS-based spatial analysis in identifying pollution hotspots and supporting location-specific air quality management strategies within urban environments.

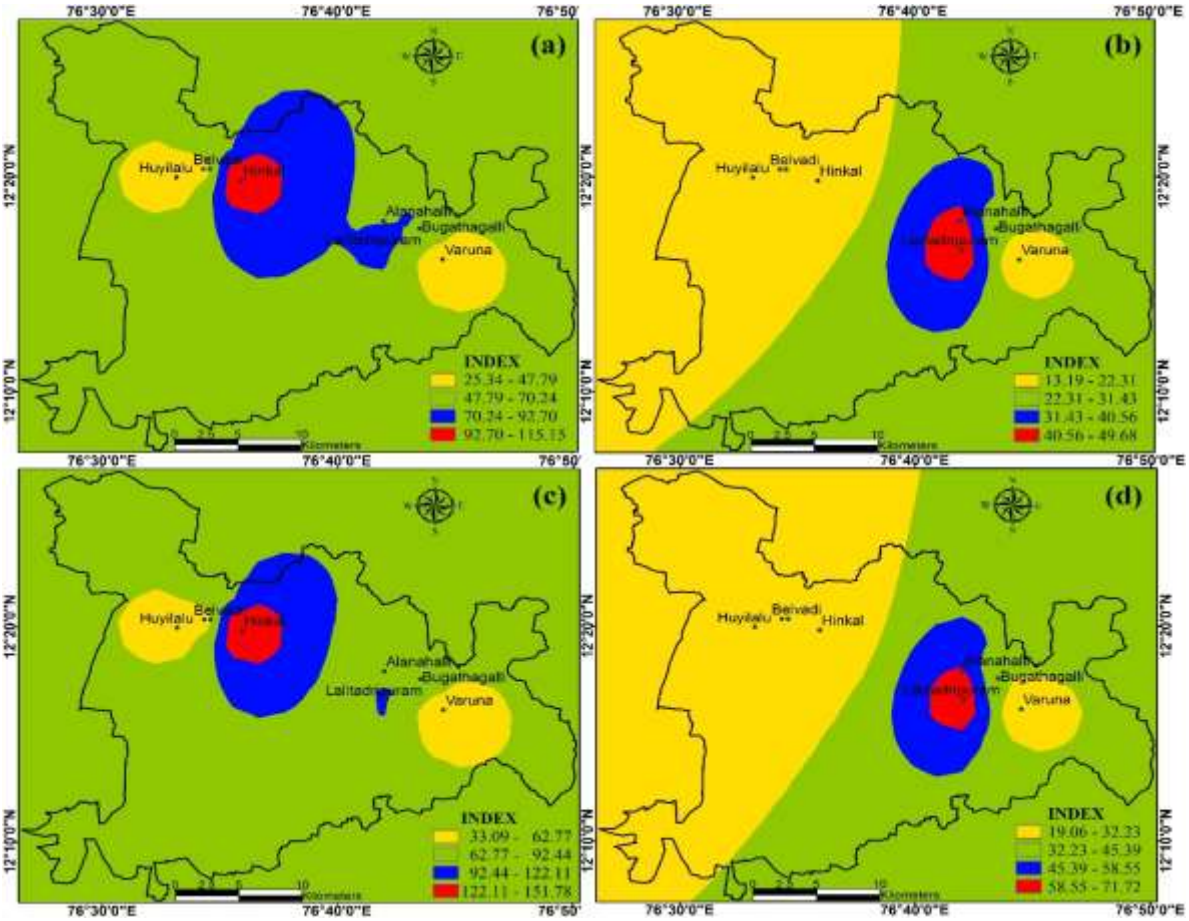
Urban GIS Mapping:



Urban (a)PM2.5 High; (b)PM2.5 Low; (c)PM1 High; (d)PM1 Low

- GIS interpolation analysis revealed significant spatial variation in $PM_{2.5}$ and PM_1 concentrations across urban Mysuru. During both high and low pollution periods, the highest particulate matter concentrations were consistently observed in Bogadi, while lower concentrations were recorded in Nazarbad and RajeevNagar.
- $PM_{2.5}$ concentrations ranged from 47.00–129.98 µg/m³ during the high pollution period and 18.00–75.99 µg/m³ during the low pollution period.
- Similarly, PM_1 concentrations ranged from 36.00–113.98 µg/m³ and 11.00–50.99 µg/m³ during high and low pollution periods, respectively. The observed west-to-east decline in pollutant concentrations indicates the influence of localized emission sources and urban activity patterns on particulate matter distribution within the city.

Rural GIS Mapping:



Rural (a) PM2.5 High; (b) PM2.5 Low; (c) PM1 High; (d) PM1 Low

- GIS-based interpolation revealed substantial spatial variability in $PM_{2.5}$ and PM_{1} concentrations across rural Mysuru. Hinkal consistently recorded the highest particulate matter concentrations during both high and low pollution periods, while Huyilalu and Varuna exhibited comparatively lower levels.
- $PM_{2.5}$ concentrations ranged from 25.34–115.15 µg/m³ during the high pollution period and 13.19–49.68 µg/m³ during the low pollution period.
- Similarly, PM_{1} concentrations ranged from 33.09–151.78 µg/m³ and 19.06–71.72 µg/m³, respectively. The spatial distribution indicates a concentration hotspot centered around Hinkal, with pollutant levels decreasing toward the peripheral rural villages, suggesting the influence of localized emission sources and urban-rural transition effects.

Sociodemographic Profile

The majority of children (52.8%) were male, and 47.2% female. Age was evenly distributed across the 36–59-month range. Approximately 60% of households were classified as nuclear families. Socioeconomically, 43.5% fell in the lower-middle and lower BG Prasad classes. Maternal education was predominantly at the primary level (45.3%). Regarding cooking fuel, 34.8% used biomass exclusively, 29.8% used mixed sources (LPG supplemented by biomass), and 35.5% used LPG only. Regarding housing, 52.3% resided in semi-permanent or kutcha dwellings with limited ventilation.

Nutritional Status

The overall prevalence of stunting (HAZ < −2 SD) was 37.8%, wasting (WHZ < −2 SD) 30.5%, and underweight (WAZ < −2 SD) 34.3%. Severe stunting (HAZ < −3 SD) was observed in 13.5% of children. These figures are consistent with NFHS-5 Mysuru district estimates, validating the representativeness of the sample.

Table 3. The nutritional status of study participants is presented.

Indicator	Category	n	%
HAZ (Stunting)	Normal (HAZ ≥ −2 SD)	249	62.3
	Mild stunting (−3 < HAZ < −2)	97	24.3
	Severe stunting (HAZ ≤ −3 SD)	54	13.5

Indicator	Category	n	%
WHZ (Wasting)	Normal (WHZ ≥ −2 SD)	278	69.5
	Moderate wasting (−3 < WHZ < −2)	87	21.8
	Severe wasting (WHZ ≤ −3 SD)	35	8.8
WAZ (Underweight)	Normal (WAZ ≥ −2 SD)	263	65.8
	Moderate underweight (−3 < WAZ < −2)	101	25.3
	Severe underweight (WAZ ≤ −3 SD)	36	9.0

Association Between Air Pollution and Nutritional Status

Chi-square analysis revealed statistically significant associations between indoor air pollution and nutritional outcomes. Indoor $PM_{2.5}$ exposure was significantly associated with both stunting (χ^2 = 49.486, p = 0.002) and wasting (χ^2 = 49.137, p = 0.015). Indoor AQI categories were significantly associated with wasting (χ^2 = 44.903, p = 0.039). Outdoor $PM_{2.5}$ exposure showed a significant association with wasting (χ^2 = 36.958, p = 0.044). No statistically significant associations were observed between outdoor air pollution exposure and stunting (p > 0.05) or between indoor AQI and underweight status (p = 0.786).

Table 4. Associations between air pollution exposure variables and nutritional outcomes are shown in.

Exposure Variable	Outcome Variable	χ^2 / Statistic	p-value
Indoor $PM_{2.5}$ category	Stunting (HAZ < −2)	χ^2 = 49.486	**0.002**
Indoor $PM_{2.5}$ category	Wasting (WHZ < −2)	χ^2 = 49.137	**0.015**
Indoor AQI category	Wasting (WHZ < −2)	χ^2 = 44.903	**0.039**
Outdoor $PM_{2.5}$ category	Wasting (WHZ < −2)	χ^2 = 36.958	**0.044**
Outdoor $PM_{2.5}$ category	Stunting (HAZ < −2)	χ^2 = 12.441	0.133
Indoor AQI category	Underweight (WAZ < −2)	χ^2 = 4.102	0.786

Discussion

This study offers empirically grounded, measurement-based evidence from a community sample across urban and rural Mysuru Taluk that indoor air pollution — particularly elevated $PM_{2.5}$ concentrations — is significantly associated with adverse nutritional outcomes among children aged 36–59 months. The findings carry scientific and practical significance, contributing locality-specific data from a South Indian secondary city to a literature that has been dominated by national ecological analyses and high-income country evidence.

The most statistically compelling finding was the significant association between indoor $PM_{2.5}$ exposure and stunting ($\chi^2 = 49.486$, $p = 0.002$). The biological pathway linking chronic $PM_{2.5}$ exposure to linear growth faltering is well established. Inhaled particulate matter triggers innate immune activation and systemic inflammation, elevating pro-inflammatory cytokines (IL-6, TNF-α) that activate hepcidin, suppress appetite via leptin-mediated mechanisms, and divert amino acids from anabolic to acute-phase protein synthesis [3]. Prendergast et al.'s nested cohort within the ZVITAMBO trial demonstrated that infants in the highest inflammatory quartile showed markedly lower length-for-age Z-scores at 12 months and higher odds of stunting [8], providing direct evidence for the inflammation-stunting pathway that air pollution activates.

The present finding is consistent with Indian evidence from Subramanian et al., who, using NFHS-3 data from 28 Indian states, found that children from biomass-fuel households had 1.41 times higher odds of stunting (95% CI: 1.28–1.55) than those from clean-fuel households [10]. Similarly, Patel et al.'s community-based study in Gujarat tribal communities found significantly higher stunting prevalence among biomass-exposed children (67.4% vs 51.5%, $p = 0.001$) when indoor $PM_{2.5}$ was 4.8 times the WHO guideline [11] — a ratio similar to the exposures observed in biomass-using households of this study. The present study found the indoor rather than outdoor $PM_{2.5}$ association to be the stronger predictor of stunting is consistent with the finding that young children in India spend the majority of their waking hours at home, and that kitchen proximity during cooking represents the highest-intensity exposure event.

Wasting showed significant associations with both indoor $PM_{2.5}$ ($p = 0.015$) and indoor AQI categories ($p = 0.039$), and also with outdoor $PM_{2.5}$ ($p = 0.044$). This convergence of both indoor and outdoor exposures on the wasting outcome — the most acute form of child undernutrition and a leading predictor of child mortality — is biologically coherent. Wasting reflects a negative energy balance in which metabolic expenditure exceeds intake; air pollution exacerbates this

balance. Fullerton et al.'s field study in rural Malawi found that higher smoke exposure was independently associated with lower WAZ scores ($\beta = -0.31$, $p < 0.001$) and higher systemic inflammatory markers consistent with these mechanisms [7]. Gordon et al.'s multi-country synthesis established that ALRI frequency was significantly associated with wasting prevalence across countries ($r = 0.67$, $p < 0.001$), providing quantitative confirmation that pollution-driven respiratory morbidity translates directly into acute nutritional deterioration [3].

The finding that outdoor $PM_{2.5}$ was significantly associated with wasting but not stunting is noteworthy. Children in Mysuru spend considerable time outdoors — in courtyards, near roadways, and at Anganwadi centres located on busy streets — exposing them to vehicular and construction-related particulate matter. The episodic nature of outdoor exposure may be more closely coupled to acute inflammatory events driving rapid weight loss (wasting) than to the chronic low-grade inflammation required to suppress linear growth (stunting), which accumulates over months to years. This distinction has practical design implications: clean cooking interventions alone will not fully protect children from the ambient pollution burden in rapidly urbanising secondary cities like Mysuru.

The markedly higher indoor $PM_{2.5}$ levels observed in biomass-using households — with mean cooking-period concentrations exceeding 250 μg/m³ compared to the typical outdoor mean of 45–60 μg/m³ in Mysuru's peri-urban areas — highlight household air pollution as the dominant, modifiable exposure. India's Pradhan Mantri Ujjwala Yojana (PMUY) scheme has provided LPG connections to millions of households; however, field studies repeatedly document that many beneficiaries continue using biomass due to the recurring cost of LPG refills and entrenched cooking practices [6]. The present finding that 34.8% of study households relied exclusively on biomass despite PMUY coverage in the study area confirms this persistent implementation gap. Mehta and Shahpar's cost-effectiveness modelling estimated that 50% $PM_{2.5}$ reduction through clean fuel adoption would reduce child underweight prevalence by 8.3 percentage points and stunting by 6.1 percentage points over five years [9] — figures that, if realised in Mysuru's approximately 45,000 under-five population, would represent a substantial and cost-efficient nutritional gain.

The absence of a significant association between indoor AQI categories and underweight ($p = 0.786$) requires careful interpretation. Underweight (WAZ < −2 SD) is a composite measure reflecting both stunting (linear growth failure) and wasting (acute weight loss), and its bi-

directional determination — by chronic environmental exposure on the one hand and acute nutritional events on the other — may have diluted the association in this cross-sectional sample. Additionally, the BG Prasad socioeconomic classification showed that a minority of households (< 10%) were in the lowest economic stratum, and these households also tended to have higher dietary diversity scores due to participation in ICDS feeding programmes, possibly moderating the pollution-underweight pathway.

Food Frequency Questionnaire (FFQ) data (presented in the supplementary tables) indicated lower food intake among children from biomass-fuel-using households compared with those from LPG-using households. Evidence from previous research has shown that prolonged exposure to $PM_{2.5}$ may reduce appetite and daily energy intake in children through respiratory irritation and systemic inflammation. In addition, air pollution may interfere with the body's ability to absorb and utilise nutrients efficiently. Together, reduced food intake and impaired nutrient utilisation may contribute to poorer nutritional outcomes among children living in biomass-fuel-using households.

The findings suggest several practical actions. Support for clean cooking fuels should be strengthened so that low-income families can regularly use LPG instead of solid fuels. Anganwadi centres should be located away from busy roads and major construction sites, with adequate ventilation to reduce children's exposure to air pollution. Nutrition programmes under ICDS should give additional attention to children living in households with high pollution exposure, as they may be at greater risk of poor growth and nutritional deficiencies. Incorporating simple air quality assessments into routine community health visits can also help identify vulnerable households and improve targeting of health and nutrition interventions.

Conclusions

This analytical cross-sectional study, conducted among 400 children aged 36–59 months across urban and rural households of Mysuru Taluk with direct measurement of ambient and indoor $PM_{2.5}$ levels, provides contextually specific evidence that indoor air pollution is significantly associated with stunting and wasting in young children. Indoor $PM_{2.5}$ was the strongest predictor of stunting, while both indoor and outdoor $PM_{2.5}$ were associated with wasting — the most clinically urgent form of child undernutrition. These findings place air pollution alongside dietary insufficiency as a structural determinant of child malnutrition in rapidly urbanising Indian secondary cities.

Clean cooking fuel transition, ventilation improvement, and integration of air quality monitoring into routine child health surveillance represent evidence-based, actionable steps to reduce the nutritional co-burden of air pollution in Mysuru and similarly situated settings. Longitudinal studies with mediation analyses are warranted to establish causal pathways and to quantify the relative contributions of inflammation, infection, and appetite suppression to the observed associations.

Strengths and Limitations

Strengths

The key strengths of this study include: (i) direct measurement of $PM_{2.5}$ levels at the household level rather than reliance on proxy indicators such as fuel type, providing a more accurate exposure assessment; (ii) simultaneous measurement of ambient and indoor pollution, enabling comparison of exposure sources; (iii) community-based anthropometric assessment following WHO standard procedures, minimising measurement bias; (iv) coverage of both urban and rural households within Mysuru Taluk, ensuring environmental and sociodemographic variability; (v) adequate sample size calculated a priori; and (vi) dietary assessment through FFQ to account for nutritional intake as a potential confounder.

Limitations

Several limitations should be acknowledged. The cross-sectional design precludes causal inference, and reverse causality cannot be excluded. Single-point 24-hour AQI measurements may not fully represent habitual exposure; ideally, repeated measurements over multiple seasons would be used. The study was conducted in a single taluk, and findings may not be generalised directly to other Indian cities or rural settings. Primary association analyses did not include multivariate adjustment for all potential confounders, including detailed infection history and micronutrient supplementation status, making the observed associations preliminary. Future studies should also explore gender-stratified analyses, given documented differences in children's time-use patterns and caregiver practices between boys and girls in Indian households.

List of Abbreviations

Abbreviation	Full Form	Abbreviation	Full Form
AQI	Air Quality Index	**MUAC**	Mid-Upper Arm Circumference
ASHA	Accredited Social Health Activist	**NAAQ**	National Ambient Air Quality
BMI	Body Mass Index	**NFHS**	National Family Health Survey
CI	Confidence Interval	**NO_2**	Nitrogen Dioxide
COPD	Chronic Obstructive Pulmonary Disease	**PM_1**	Particulate Matter ≤1 μm in aerodynamic diameter
FFQ	Food Frequency Questionnaire	**$PM_{2.5}$**	Particulate Matter ≤2.5 μm in aerodynamic diameter
HAP	Household Air Pollution	**SPSS**	Statistical Package for the Social Sciences
HAZ	Height-for-Age Z-score	**UNICEF**	United Nations Children's Fund
ICDS	Integrated Child Development Services	**WAZ**	Weight-for-Age Z-score
IEC	Institutional Ethics Committee	**WHZ**	Weight-for-Height Z-score
LPG	Liquefied Petroleum Gas	**WHO**	World Health Organization
LMIC	Low- and Middle-Income Countries		

Declarations

Ethics Approval and Consent to Participate

Ethical clearance was obtained from the Institutional Ethics Committee of JSS Academy of Higher Education and Research, Mysuru. Written informed consent was obtained from the primary caregiver of all participant children before enrolment. Participation was entirely voluntary.

Availability of Data and Materials

The datasets used and/or analysed during this study are available from the corresponding author on reasonable request.

Competing Interests

The authors declare that they have no competing interests.

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Authors' Contributions

BSB (Bhimanagouda S Basanagoudar) designed the study, collected data, performed the statistical analysis, interpreted the results, and drafted the manuscript. DMS (D.M. Shilpa) conceptualised the study, provided methodological guidance, and critically revised the manuscript. MCM (Manjunath M. C.) provided methodological guidance and critically revised the manuscript. All the authors read and approved the final manuscript.

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Clinical trial registration

This is not a clinical trial

Trial registration

Clinical trial number: Not applicable.

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