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Determinants of Acute Respiratory Infection among Children in India: Evidence from the National Family Health Survey-5

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Abstract

Acute respiratory infection (ARI) is a leading cause of morbidity among children under five years of age in low- and middle-income countries, where household air pollution from polluting cooking fuels is a recognised risk factor. This study examines the association between cooking-fuel exposure and ARI among Indian children under five, with particular attention to rural–urban variation. Using cross-sectional data from the fifth round of the National Family Health Survey (NFHS-5), we applied survey-weighted methods to account for the complex sampling design. Descriptive and bivariate statistics characterised prevalence patterns, and survey-weighted multivariable logistic regression models estimated the association between cooking-fuel exposure and ARI while adjusting for child, maternal, and household characteristics. An interaction term between cooking fuel and place of residence was tested for effect modification. ARI was more prevalent among children exposed to polluting fuels than among those in clean-fuel households. In unadjusted models, both indoor and outdoor polluting fuels were associated with higher odds of ARI; however, these associations attenuated to non-significance after adjustment for socioeconomic and demographic factors, indicating substantial confounding. Child age, sex, household wealth, and household smoking emerged as strong correlates of ARI. The interaction analysis showed that the cooking-fuel association varied by residence, with outdoor polluting fuels associated with higher odds of ARI in rural but not urban households. Cooking-fuel exposure is associated with ARI in Indian children, but its apparent effect is conditional on socioeconomic and environmental context. Policies that promote clean-fuel adoption, reduce household smoke, and improve rural housing may help lower the ARI burden.

Keywords: Acute respiratory infection; Cooking fuel; Household air pollution; Under-five children; Rural–urban disparities

Introduction

Acute respiratory infections (ARIs) remain a major public health concern among children under five years of age (Khanday et al., 2024), especially in low- and middle-income countries (LMICs) (Adesanya and Chiao, 2017). ARIs encompass both upper and lower respiratory tract illnesses, including the common cold, pneumonia, and influenza and present with symptoms such as cough, shortness of breath, rapid breathing, and chest indrawing that reflect varying degrees of respiratory compromise. The burden is concentrated in LMICs, where socioeconomic inequality, inadequate housing, and environmental exposures such as indoor air pollution interact to shape child health outcomes (Saleh et al., 2020). Globally, Pneumonia alone caused about 15% death of under 5-year child, making ARIs a leading contributor to childhood mortality and hospitalisation (Abul and Azad, 2009; Hug et al., 2020).



In India, ARIs cause approximately 400,000 under-five deaths each year (Hasan et al., 2022). The combined effects of poor indoor air quality, overcrowding, and limited access to healthcare compounds heightens children's vulnerability. High utilisation of pollutant cooking fuels, especially in economically disadvantaged households, exposes children to toxic combustion products during a critical window of physiological development (Balmes, 2019). A growing evidence base indicates that the determinants of ARI are not confined to isolated household exposures but are embedded in broader structural and environmental contexts (Sollari Lopes et al., 2022).

Conceptually, there has been a shift in understanding of ARI from a narrow biomedical framing to an integrated perspective that recognises the interplay between biological susceptibility, environmental exposure, and social determinants (Cui et al., 2024). In the case of the exposure–disease–stress model, child health outcomes arise from the cumulative effects of physical environments, socioeconomic conditions, and stressors within context. Evidence from the developing world indicates that compounded exposure (indoor pollution, household poverty, and community-level disadvantage) increases the risk of ARI rather than isolated exposure (Dietler et al., 2021).

In India, most prior research has focused on isolated determinants such as indoor air pollution or maternal characteristics, leaving a gap in understanding how multiple factors act simultaneously to shape ARI risk. In particular, household exposures, socioeconomic conditions, and behavioural factors have rarely been analysed together in the same framework. This gap limits the scope of effective interventions; programmes and policies tend to tackle one risk factor at a time and fail to consider the structural context.

To address this gap, the present study adopts a multilevel, integrated analytical approach to ARI among Indian children. Using NFHS-5 data, it examines the relative contributions of household environmental conditions, behavioural factors, and socioeconomic status to ARI outcomes. The study contributes to a growing body of research that supports a multi-factorial rather than a single-factor explanation of child health. By moving beyond a fuel-centric view and applying interaction and stratified analysis to better understand the social and structural determinants and drivers of India's ARI burden, as well as the environmental exposures.

Methodology

Data source

This study used data from the National Family Health Survey phase 5, which is a nationally representative household survey conducted in India under the Demographic and Health Survey (DHS) programme.

Study population

The analysis focuses on approximately 220,000 children aged 0–59 months. The sample was restricted to children under 5 years old.

Dependent variable

The outcome is broadly defined as ARI, indicated by the presence of cough with rapid or difficult breathing in the 2 weeks prior to the survey. It was recorded as a binary variable (1 = ARI symptoms present; 0 = absent); “don't know” and “other” responses were not included.

Key independent variable: cooking-fuel exposure

Household cooking-fuel exposure was constructed by combining fuel type with cooking location and classified into three categories: (i) clean fuel (biogas, liquefied petroleum gas, natural gas, and electricity); (ii) polluting fuel used outdoors (coal, lignite, charcoal, wood, straw, shrubs, grass, agricultural crop residue, and animal dung); and (iii) polluting fuel used indoors. This classification captures both the type of environmental exposure and the contextual difference between rural and urban settings.

Covariates

Models adjusted for child characteristics (age group: 0–5, 6–11, 12–23, 24–35, and 36–59 months; sex; and birth order: first, second, third, and fourth or higher); maternal characteristics (educational attainment, age at marriage, and media exposure); and household characteristics (wealth index, from poorest to richest quintile; place of residence, urban or rural; and household smoking exposure).

Statistical analysis

Analyses proceeded in stages. Survey-weighted descriptive statistics (weighted frequencies and percentages) were generated in Stata using the svy command suite to accommodate the complex sampling design. Bivariate analyses were then used to assess unadjusted associations between ARI and each independent variable. Multivariable associations were estimated using survey-weighted logistic regression (svy: logistic), with odds ratios (ORs) and 95% confidence intervals (CIs) reported. Confounding was examined through a sequential modelling strategy: Model 1 included only cooking-fuel exposure; Model 2 added child-level characteristics; Model 3 added maternal

and household socioeconomic characteristics; Model 4 added household smoking and place of residence; and Model 5 introduced an interaction term between cooking-fuel exposure and place of residence to test for effect modification. All analyses accounted for the survey design to ensure unbiased estimates.

Results

The association between cooking-fuel exposure and ARI among children under five was estimated using survey-weighted logistic regression across five sequential models (Table 2).

In the unadjusted model (Model 1), children in households using polluting cooking fuels had higher odds of ARI than those using clean fuels. Outdoor polluting fuels were associated with 25% higher odds (OR = 1.25; 95% CI: 1.15–1.36; $p < 0.001$) and indoor polluting fuels with 18% higher odds (OR = 1.18; 95% CI: 1.11–1.26; $p < 0.001$). The baseline prevalence of ARI in clean-fuel households was 5.8%. This model reflects the crude environmental association before accounting for child, maternal, and household factors. Adjusting for child-level characteristics (Model 2) modestly attenuated but did not eliminate the fuel association (outdoor OR = 1.23; indoor OR = 1.17). Age was strongly predictive: children aged 6–11 months were 1.51 times as likely to have ARI as those under six months, whereas children aged 36–59 months were at lower risk (OR = 0.83). Female children had lower odds than males (OR = 0.86), and fourth-or-higher birth order was associated with increased odds (OR = 1.13), possibly reflecting resource dilution or crowding.

With the addition of maternal and household characteristics (Model 3), the fuel association was no longer statistically significant, with only a marginal inverse association for indoor polluting fuel (OR = 0.93; $p = 0.06$). Maternal secondary education was positively associated with ARI (OR = 1.14)—a paradoxical finding most plausibly attributable to reporting bias, as better-educated mothers may more readily recognise and report symptoms. Later age at marriage (21+ years) was associated with lower odds (OR = 0.87), and media exposure with higher odds (OR = 1.13), again consistent with greater awareness or reporting. A strong wealth gradient was evident: children in the richest households had 38% lower odds of ARI than those in the poorest. Rural residence showed a borderline association (OR = 1.10). Once socioeconomic characteristics were included, the direct association between cooking-fuel exposure and ARI became non-significant, and maternal and household factors emerged as the dominant correlates.

Model 4 additionally adjusted for household smoking and place of residence. Indoor polluting fuel remained marginally associated with ARI (OR = 0.92; $p = 0.04$), while outdoor polluting fuel was non-significant (OR = 0.97; 95% CI: 0.89–1.06; $p = 0.55$). However, age remained influential (6–11 months: OR = 1.51; 12–23 months: OR = 1.26; 36–59 months at lower risk), female sex was associated with 13% lower odds, and birth order was no longer significant after adjustment. Primary education (OR = 1.11) and secondary education (OR = 1.14) were positively associated with higher odds, whereas later marriage (21+ years) was negatively associated with lower odds (OR = 0.87; $p < 0.001$). The increased media exposure (OR = 1.13; $p = 0.001$) was again likely due to greater awareness and reporting. The wealth gradient continued, and household smoking was modestly associated with higher odds (OR = 1.06; $p = 0.047$). Rural residence was marginal (OR = 1.10; $p = 0.066$). In general, socioeconomic and household conditions, particularly wealth, maternal factors, and smoking, are more significant factors influencing ARI than cooking fuel alone. In model 5, the interaction between cooking-fuel exposure and place of residence was added. The relationship was only found in some contexts; ARIs were inversely associated with outdoor polluting fuel in urban households (OR = 0.65; $p = 0.01$) but were associated with higher odds in rural households (OR = 1.53; 95% CI: 1.10–2.14), though precision was limited given the wide interval. The indoor-fuel interaction was not significant (OR = 0.93; $p = 0.55$). Child-level patterns did not change (6–11 months OR = 1.51; 12–23 months OR = 1.26; 36–59 months OR = 0.83; female OR = 0.86), and the household smoking remained a risk factor (OR = 1.06), though not as strong as the wealth gradient. Once the interaction was taken into account, rural residence was no longer significant. Taken together, Model 5 indicates that place of residence modifies the association between cooking-fuel exposure and ARI, with outdoor polluting fuels more strongly associated with ARI in rural settings, pointing to the need for context-specific interventions.

Table 1. Descriptive characteristics of the study population

Variable	N	% (weighted)
Key predictor variables		
Cooking Fuel Exposure		
Clean Fuel (Reference category)	99,679	50.29
Pollutant fuel (outdoor exposure)	38,814	16.38
Pollutant fuel (indoor exposure)	82,534	33.33
Child level predictor		
Age		

0–5 months	22,891	10.22
6–11 months	21,568	9.91
12–23 months	43,097	19.59
24–35 months	43,712	19.82
36–59 months	89,759	40.45
Sex		
Table 1 (continued)		
Variable	N	% (weighted)
Male	114,263	51.89
female	106,764	48.11
Birth order		
First	84,442	39.07
Second	73,246	33.92
Third	34,591	15.24
Fourth+	28,748	11.76
Maternal level predictors		
Education level		
No education	47,835	20.97
Primary	28,290	12.19
Secondary	114,177	50.87
Higher	30,725	15.96
Age at marriage		
<18	68,583	33.22
18–20	80,282	36.66
21+	72,162	30.12
Media Exposure		
Exposure	156,404	71.62
No exposure	64,623	28.38
Household-level predictor		
Wealth index		
poorest	59,326	24.17
poorer	51,422	21.58
middle	42,920	19.54
richer	37,422	18.57
richest	29,937	16.14
Household smoking exposure		
No smoking	108,083	54.26
Smoking present	112,943	45.74
Place of residence		
Urban	45,303	26.96
Rural	175,724	73.04

Source: Author's analysis based on NFHS-5 (2019–21) data.

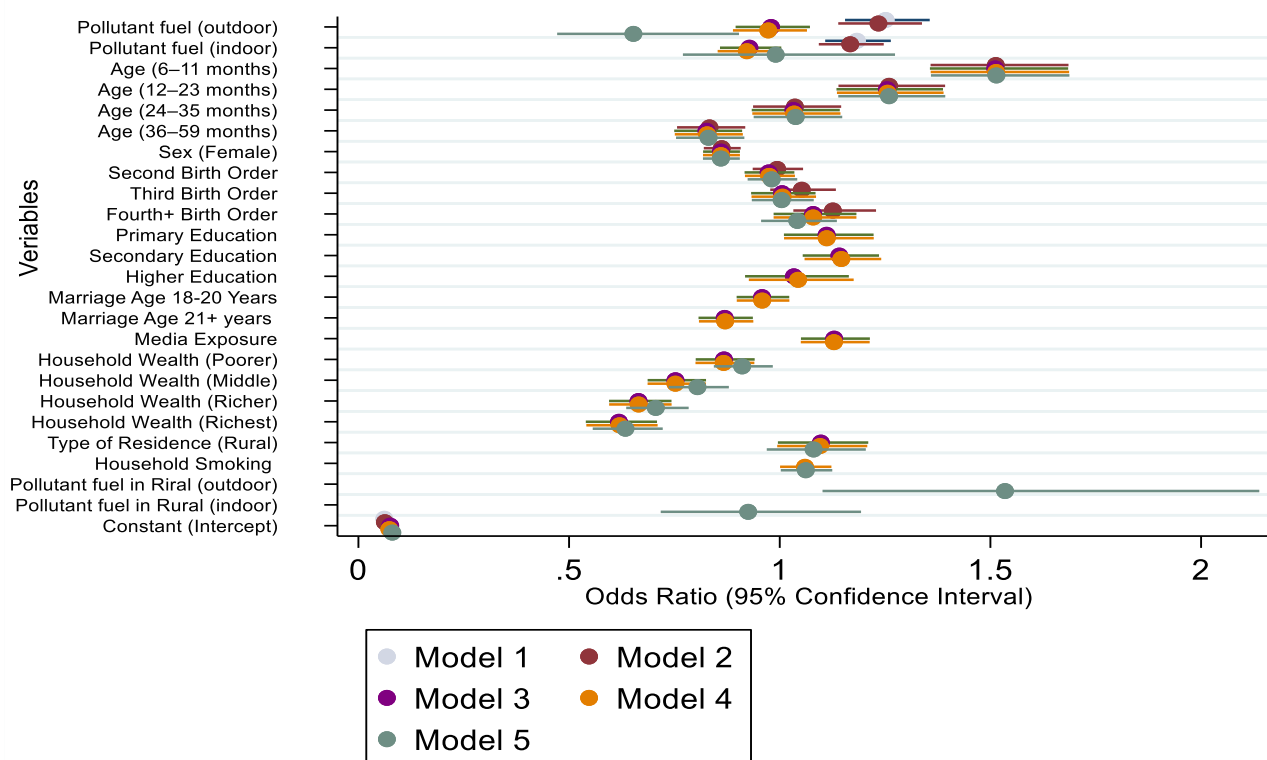
Discussion

This study shows that cooking fuel use is directly linked to an increased risk of acute respiratory infection (ARI), but the association is strong and significantly moderated by other socioeconomic and environmental factors. Children living in households using outdoor and indoor polluting fuels had unadjusted ARI risks that were 25% and 18% higher, respectively. But these associations were reduced to non-significance and, in the case of indoor fuel, even to an inverse marginal association after controlling for household wealth, maternal education and tobacco smoking. The pattern points to significant socioeconomic confounding: poverty is linked to biomass fuel use and to a child's intrinsic vulnerability. The findings are in line with the previous studies, which found that the direct association between cooking fuel and respiratory outcomes was found to be confounded by socioeconomic status (Mondal and Paul, 2020; Rana et al., 2019). As previously mentioned in the literature, household wealth acts as a

"flexible resource" which can help households in reducing and adapting to environmental risks (Link and Phelan, 1995). With wealth and education included, they can explain the variance previously attributed to fuel type, reflecting better housing conditions, less overcrowding, and better nutrition, which improves respiratory resilience (Mondal and Paul, 2020). Moreover, the independent effect of fuel is suppressed by the presence of a smoker, indicating a synergistic effect of indoor air pollutants, such that the presence of a smoker makes the respiratory burden from inefficient biomass combustion more severe (Mondal and Paul, 2020).

Fig. 1. Forest plot of adjusted odds ratios for ARI among children under five

Association Between Cooking Fuel Exposure and ARI: Forest Plot of Logistic Regression Models



Source: Author's analysis based on NFHS-5 (2019–21) data.

Table 2. Results of survey-weighted logistic regression models examining the association between cooking fuel exposure and ARI among children under five

Variables	Model 1	p-value	Model 2	p-value	Model 3	p-value	Model 4	p-value	Model 5	p-value
Cooking Fuel (Ref: Clean)	OR (95% CI)		AOR (95% CI)		AOR (95% CI)		AOR (95% CI)		AOR (95% CI)	
Pollutant fuel (outdoor)	1.25 (1.15-1.36)	<0.001	1.23 (1.14-1.34)	<0.001	0.98 (0.90-1.07)	0.60	0.97 (0.89-1.06)	0.50	0.65 (0.47-0.90)	0.010
Pollutant fuel (indoor)	1.18 (1.11-1.26)	<0.001	1.17 (1.09-1.25)	<0.001	0.93 (0.86-1.00)	0.060	0.92 (0.85-1.00)	0.040	0.99 (0.77-1.27)	0.940

Key Predictor Variable Child Characteristics

Variables	Model 2	p-value	Model 3	p-value	Model 4	p-value	Model 5	p-value
Age group (Ref: 0-5 months)								
6-11 months	1.51	<0.001	1.51	<0.001	1.51	<0.001	1.51	<0.001
12-23 months	1.26	<0.001	1.25	<0.001	1.26	<0.001	1.26	<0.001
24-35 Months	1.04	0.49	1.04	0.49	1.04	0.49	1.04	0.47
36-59 Months	0.83	<0.001	0.83	<0.001	0.83	<0.001	0.83	<0.001

Sex (Ref: Male)								
Female	0.86	<0.001	0.86	<0.001	0.86	<0.001	0.86	<0.001
Birth Order (Ref: First)								
Second	0.99	0.84	0.99	0.84	0.98	0.53	0.98	0.53
Third	1.05	0.17	1.05	0.17	1.00	0.90	1.00	0.90
Fourth+	1.13	0.007	1.12	0.01	1.04	0.35	1.04	0.35

Mother's Characteristics

Variables	Model 3	p-value	Model 4	p-value
Education (Ref: No Education)				
Primary	1.11*	0.02	1.11*	0.02
Secondary	1.14**	0.01	1.15**	0.01
Higher	1.02	0.80	1.02	0.80
Marriage Age (Ref: <18)				
18-20	0.95	0.20	0.95	0.20
21+	0.87***	<0.001	0.87***	<0.001
Media exposure (Ref: No exposure)				
Yes	1.13**		1.13**	

Household Characteristics

Variables	Model 3	p-value	Model 4	p-value	Model 5	p-value
Wealth (Ref: Poor)						
Poorer	0.87	<0.001	0.87	<0.001	0.91	0.017
Middle	0.75	<0.001	0.75	<0.001	0.80	<0.001
Richer	0.66	<0.001	0.67	<0.001	0.70	<0.001
Richest Table 2 (continued)	0.62	<0.001	0.62	<0.001	0.63	<0.001
Smoking in House (Ref: No smoking in house)						
Smoking in the house			1.06	0.040	1.06	0.041

Contextual Factors

Variables	Model 3	p-value	Model 4	p-value	Model 5	p-value
Residence (Ref: Urban)						
Rural	1.10	0.06	1.10	0.06	1.08	0.163
Interaction (Fuel × Residence)						
Outdoor × Rural					1.53	0.011
Indoor × Rural					NS	0.549

Source: Author's analysis based on NFHS-5 (2019–21) data.

This risk is further delineated by both biological and developmental factors, which present a unique age-specific vulnerability gradient with a peak among infants aged 6–23 months, supported by both biological and developmental plausibility (Hasan et al., 2022). In this age group, children are at a crucial physiological turning point, with underdeveloped immune responses and lung morphology defined by underdeveloped lung epithelial linings and narrower airways (Balmes, 2019; Rana et al., 2019). In terms of morphology, children in this cohort have a larger surface area of lungs per kg of body weight, which means that they breathe more polluted air than older children, up to 50% more air in normal conditions. This increased susceptibility has been quantified using meta-analytic evidence, and the odds ratio for children under 2 years of age (OR = 1.96) is significantly higher than that for the overall under-5 age group (OR = 1.79) (Dherani et al., 2008). This biological vulnerability is often exacerbated by cultural and behavioural factors related to exposure (Rana et al., 2019); infants and toddlers are often kept very close to the mother when biomass is being burned (Balmes, 2019; Mondal and Paul, 2020). These children are exposed for long periods to high levels of PM and CO, either carried on the mother's back or placed to sleep near the cooking area (Adesanya and Chiao, 2017; Balmes, 2019; Rana et al., 2019). Declining risks of ARI symptoms in older preschool-aged cohorts may be related to maturing respiratory defences and increased mobility away from the hearth as children age (Abul and Azad, 2009; Hasan et al., 2022).

The study also reveals a "maternal-education paradox" in that their background education and exposure to media were associated with a greater likelihood of reported ARI (Mondal & Paul, 2020). This is most likely due to surveillance and reporting bias, not to an actual rise in biological risk (Adesanya and Chiao, 2017; Dietler et al., 2021; Sulistyorini et al., 2022). Health-literate and empowered mothers are more likely to be aware of respiratory symptoms and to identify and report them in survey interviews, likely because they have greater exposure to the media (Abul and Azad, 2009). This interpretation corroborates Dietler et al. (2021), who found that self-reported

child health outcomes from surveys are more common among respondents with higher levels of education (Manesh et al., 2007). The results provide further evidence of the importance of considering survey-based morbidity data within a framework that accounts for maternal characteristics that influence morbidity reporting, but should not be interpreted as a mechanism. As far as gender differences are concerned, the higher incidence of ARI among boys is consistent with the results from the previous NFHS (Hasan et al., 2022) and could be attributed to a biological “male disadvantage” in immunity; however, regional variations in parent care-seeking behaviours and symptom reporting should also be taken into account (Markle and Fish, 2014). However, in some parts of the world, there are indications that girls may be at greater risk because gendered expectations push them towards household responsibilities in the cooking space, where they are more likely to be exposed to indoor pollutants (Sulistiyorini et al., 2022).

These risks are also modified by spatial context, as suggested by several important interaction models that found that the health effects of cooking fuels are not constant but are determined by the spatial environment (Amadu et al., 2023). The significant rural–urban difference is that the use of outdoor polluting fuels is strongly positively associated with the risk of ARI in rural areas, with the OR reaching 1.53, which may be explained by the way in which households are built and the nature of the biomass fuel they use, which can create a situation of smoke trapping in the immediate vicinity of the household, and/or a lack of adequate site ventilation or ineffective dispersion of biomass emissions from semi-enclosed buildings (Khanday et al., 2024). By contrast, urban ARI risk indicates a more complex air-quality environment. While in urban settings there is a greater likelihood of access to cleaner energy, the potential for health impacts can be undermined by high levels of ambient air pollution caused by emissions from industry and road vehicles (Sollari Lopes et al., 2022). Increased population density and overcrowding in urban slums can also decrease the ventilation and extend the residence time of PM. Therefore, the risk in rural areas appears to be mainly driven by high-intensity biomass use, whereas the urban risk appears to be linked to the combination of energy selection and more polluted ambient air conditions (Amadu et al., 2023). Finally, the study provides support for moving beyond a limited and fuel-focused framework to a more comprehensive one that recognises the interplay between social determinants of health and biological susceptibility.

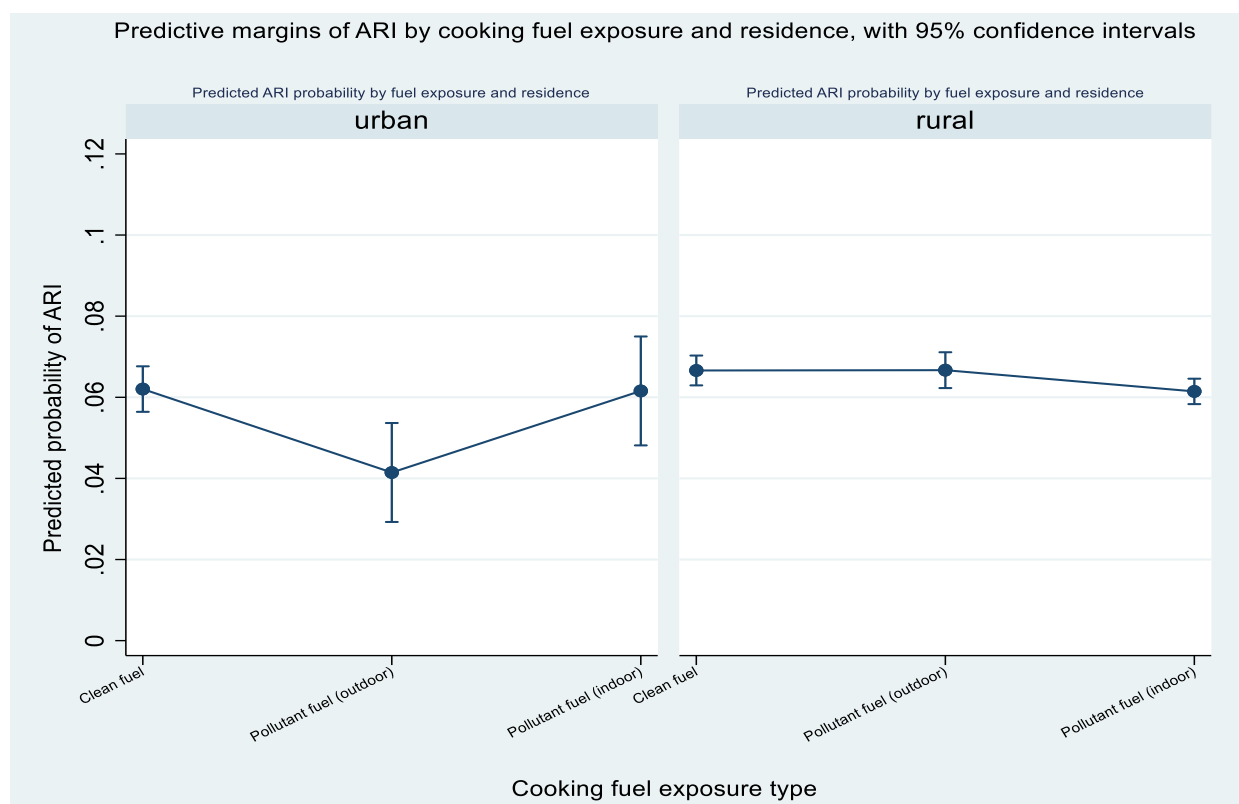


Fig. 2. Predicted probability of ARI by cooking fuel exposure and place of residence

Source: Author's analysis based on NFHS-5 (2019–21) data.

Conclusion

This study provides evidence that cooking-fuel exposure is associated with ARI among children under five in India, but that this association is conditioned by socioeconomic, household, and contextual factors. Younger age (6–23 months), male sex, household smoking, and poverty were consistently associated with higher risk, whereas greater household wealth and markers of maternal empowerment were associated with lower risk. The rural–urban interaction is a useful reminder of the need for context-specific responses, particularly to biomass fuel use, ventilation, and household smoking in rural houses.

There are several policy implications. Clean-fuel programmes such as the Pradhan Mantri Ujjwala Yojana should be strengthened and paired with awareness-creation initiatives for the rural households. Combining ARI prevention with programmes on maternal education and child health programmes may further reduce the burden. Future research should employ longitudinal designs to clarify causal pathways and to evaluate the interactive effects of environmental exposures and the socioeconomic environment.

Strengths and limitations

The estimates in this study are robust and generalisable, as the study is based on a large, nationally representative sample and the survey-weighted methods used here account for the complex NFHS-5 sampling design. There are limitations to interpretation, however. First, the cross-sectional design allows associations to be identified but does not allow for causal inference, and the sequential attenuation of the fuel effect is consistent with confounding but does not confirm it. Second, symptoms of ARI are based on maternal report of symptoms in the prior two weeks, which introduces recall and reporting bias, a limitation pertinent to the findings regarding maternal education and media exposure. Third, the rural interaction estimate, though important, is not exact. These limitations call for selective and associative interpretation of the findings.

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Author Contributions

SS, DK and DS conceived the concept, wrote and approved the manuscript.

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Competing interest

The authors declare no competing interests.

Ethics approval

Not applicable.



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