Association of Exposure to Indoor Air Pollution with Unhealthy Symptoms among Middle-aged and Older Adults in India: Evidence from a Large-scale Survey

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ABSTRACT

BACKGROUND: The usage of solid cooking fuels is widely prevalent in low and middle-income countries, including India, and contributes to indoor air pollution (IAP), which has detrimental health effects. Moreover, time spent inside the house increases as people age. In this context, the present study tried to understand the association between exposure to indoor air pollution and unhealthy symptoms, including shortness of breath, dizziness, headache, fatigue, wheezing, and cough among middle-aged and older adults in India.

METHODS: We extracted the unit-level individual data (N = 63 790**)** from the Longitudinal Aging Study in India (LASI)-Wave 1 (2017-2018). The statistical analyses used were Chi-square test and binary logistic regression, which estimated the odds ratio to identify the determinants of the unhealthy symptoms.

RESULTS: The odds of shortness of breath (adjusted OR: 1.14, 99% CI: 1.05-1.23), dizziness (adjusted OR: 1.28, 99% CI: 1.21-1.35), fatigue (adjusted OR: 1.32, 99% CI: 1.26-1.39), wheezing (adjusted OR: 1.30, 99% CI: 1.19-1.42), and cough (adjusted OR: 1.36, 99% CI: 1.27-1.45) were higher among individuals from households where solid cooking fuels was used. Similarly, the odds of shortness of breath, headache, wheezing, and cough were higher among individuals with a household member who smoked inside the house. The results indicated that the odds of shortness of breath, headache, and cough were significantly lower among participants exposed to incense use.

CONCLUSION: Based on the results of this study, we suggest developing programs to combat the sources of indoor air pollution and the associated unhealthy symptoms, especially in rural settings. It is also important to bring awareness and practice clean fuel usage at individual and community levels to improve population health.

PLAIN LANGUAGE SUMMARY

This study is the first of its kind to explore indoor air pollution and unhealthy symptoms among a large sample in India. We believe it will contribute significantly to the global literature on indoor pollution and health outcomes.

KEYWORDS: Unhealthy symptoms, indoor air pollution, aging adults, India

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Introduction

Air quality is one of the important determinants of individuals' health and well-being. Indoor and outdoor factors contribute to the air quality. Outdoor pollution is majorly attributed to industries, vehicle emissions, and construction works, while indoor air pollution results from using solid fuels for cooking, smoking inside the house, using incense, and other activities. Indoor air pollution is considered to be one of the leading environmental causes of disability and deaths worldwide.[1] The World Health Organization (WHO)[2] in 2020 estimated that globally, 3.2 million deaths were attributed to indoor air pollution annually. The primary source of household air pollution is the combustion of solid fuels for cooking, such as wood, coal, dung, crop residuals, and other end-uses.[3]

The other sources include smoking and emissions from certain products and building materials.[4] Many harmful substances are released during the combustion and remain indoors. The hours of cooking and poor ventilation increase the exposure to harmful substances for the habitants, especially causing ill effects to women, children, older adults, and individuals with chronic health conditions as they spend a significant proportion of time indoors.[5] In addition, the outdoor factors also affect indoor air quality,[6] suggesting the association between the both. Urbanization has led to lifestyle changes in the past few decades, with more time spent indoors.[7]

As most of human life is spent indoors, it becomes essential to have a safer environment. Indoor air pollution is one of the top 5 environmental hazards that are detrimental to health and quality of life[8] as it causes a range of non-communicable diseases, including vascular and ischemic heart diseases, pulmonary obstruction, stroke, and lung cancer.[2] In addition, indoor air pollution was associated with asthma-like symptoms,

decreased pulmonary functioning[9] and angina,[10] and decreased cognitive health.[11] Further, exposure to indoor air pollution increased the risk of cardiorespiratory, maternal, and pediatric issues compared to individuals with no exposure.[12] Subsequently, this has become a prime public health concern[13,14] as the cumulative effect of it is life-threatening. Though there is a substantial decrease in the use of solid fuels for cooking globally, the absolute number is increasing, especially in low and middle-income countries.[5]

India, one of the middle-income countries, has been ranked third in poor air quality among the 134 countries assessed in the recent World Air Quality Report.[15] The mortality rates due to household air pollution decreased from the 1990s. However, 17.8% of total deaths in India are attributed to air pollution, mainly due to ambient particulate matter and household air pollution.[16] The use of solid fuels is higher among developing nations,[17] like India, with more than 50% of households in rural areas using solid fuels.[18,19] In addition, as individuals age, a major proportion of their time is spent indoors due to functional limitations. Although the studies have identified the association between household air pollution and chronic health conditions in general, to our knowledge, minuscule studies exist in the context of specific unhealthy symptoms in India. Also, generating evidence on unhealthy symptoms among the aging population and its association with indoor pollution will be insightful in developing appropriate interventions.

A specific set of unhealthy symptoms was considered that marks the potential association with various diseases, including respiratory and cardiovascular diseases[20-23] with its higher impact in low- and middle-income countries.[24] Therefore, the current study aimed to understand the association between exposure to indoor pollution and unhealthy symptoms, including shortness of breath, dizziness, headache, fatigue, wheezing, and cough, along with occupation-related health behaviors, health-related factors, and a range of socioeconomic-demographic variables among middle-aged and older adults.

Methods

Data and sample

The study utilized data from the Longitudinal Aging Study India (LASI) – Wave 1, conducted between 2017 and 2018. The data included information about socioeconomic, health, psychosocial, and other aspects associated with the aging population in India, with a major proportion of the sample from rural settings. The data was collected from 73396 adults aged 45 years and above, along with their spouses irrespective of age, representing all Indian states and union territories. The survey adopted 3-stage and 4-stage sampling designs for rural and urban areas, respectively.[25] The present study considered only middle-aged older adults aged 45 years and above. After removing the missing data, we considered 63 790 aging adults (Male = 29 688; Female = 34102) for the final analysis (Refer to Figure 1).

Measures

Outcome variable: Unhealthy symptoms

Unhealthy symptoms indicate self-reported health symptoms that could underly a potential disease or health status. We have considered those symptoms as common indications of various disease patterns. The question assessed the unhealthy symptoms: "Have you had any of the following persistent or troublesome problems in the past 2 years?" with the list of 6 unhealthy symptoms that include 1. shortness of breath while awake; 2. persistent dizziness or light-headedness; 3. persistent headaches; 4. severe fatigue or exhaustion; 5. wheezing or whistling sound from the chest; 6. cough with or without phlegm. The response to these symptoms was self-reported and grouped as "yes" or "no."

Predictor variables: In-door air pollution

This was assessed through questions related to the type of cooking fuel, whether a household member smoked inside the house or used incense inside the house. The responses to the type of cooking fuel were categorized as clean (combining Liquefied Petroleum Gas (LPG), Biogas, and Electric) and solid cooking fuels (combining kerosine, coal, crop residue, wood, and dung cake). The responses to the other 2 air pollution sources, "Does any usual member of your household smoke inside the home?" and "Do you or your household member use incense sticks (Agarbatti)/mosquito coil/liquid vaporizer/-any card inside the house?" were classified as "yes" indicating the exposure to this in-house pollution or "no."

Control variables

Occupation-related factors: This includes 2 factors: (1) current work status and (2) work-limiting health conditions. The responses to current work status were clustered into "never worked," "homemakers," "currently not working," and "currently working." The work-limiting health conditions were assessed using the question, "Do you have any impairment or health problem that limits the kind or amount of paid work you can do?" the responses were grouped into "yes," "no," and "others/not working."

Health behavior factors: This category includes primary health behaviors such as alcohol consumption, smoking, and involvement in physical activity. Each of these factors holds a different response category. The response for alcohol consumption was grouped as "never" and "ever"; smoking habits were classified as "never", "quit," and "currently smoking." Furthermore, the participant's responses to physical activity were categorized into 5 groups: "every day," "more than once a week," "once a week," "1 to 3 times a month," and "hardly ever or never."

Health-related factors: This consists of 3 factors: Self-Rated Health (SRH), Activities of Daily Living (ADL), and

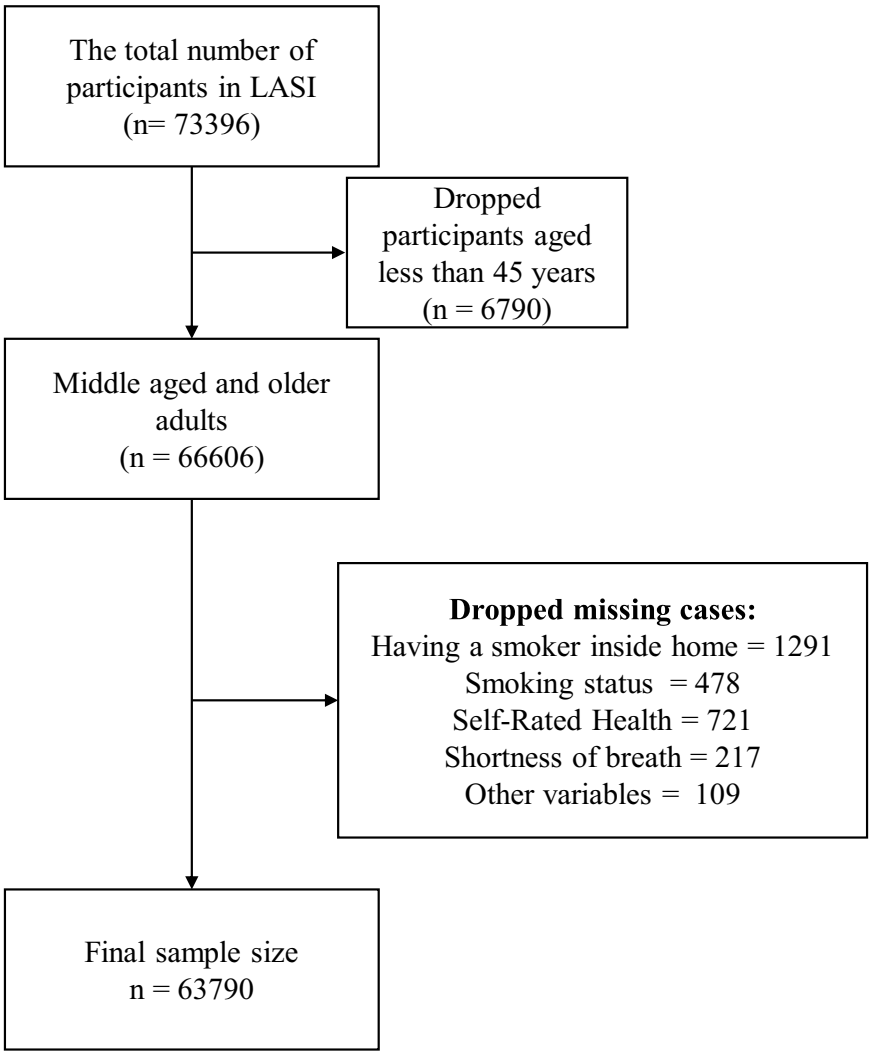

Figure 1. Participants selection criteria.

Instrumental Activities of Daily Living (IADL). The SRH was assessed by asking participants, "How is your health in general? Would you say it is very good, good, fair, poor, or very poor?" The responses to the SRH question, with this 5-point scale, were clustered into "good" (if they responded very good, good, and fair) and "poor" (if they responded poor and very poor). ADL and IADL were measured based on difficulties in 6 and 7 activities related to everyday functioning, respectively. ADL includes dressing, walking, bathing, eating, using the toilet and getting out of bed. IADL includes difficulties in cooking, shopping, making telephone calls, taking medications, working around the house/gardening, managing money and movement. The ADL and IADL were assessed by asking the participants, "Please tell me if you have any difficulty with these because of a physical, mental, emotional, or memory problem. Please exclude any difficulties you expect to last less than 3 months. The responses were categorized as "low" (if any difficulty was reported) and "high" (if no difficulty was reported) for ADL and IADL items.

Socioeconomic-demographic variables: This includes age (in years), gender, years of education (no schooling, 1-5 years, 6-10 years, and more than 10 years), household economic status (poorest, poorer, middle, richer, richest) and social class [scheduled tribe (ST), scheduled caste (SC), other backward class (OBC), and others] and residency type (rural and urban). The household economic status was calculated by standardizing the expenditure of 11 foods and 29 non-food items to a 30-day reference period using the expenditure data of each household.

Statistical analysis

First, we conducted a descriptive analysis to understand the characteristics of the study sample. Second, a Chi-square analysis was run to estimate the prevalence of unhealthy symptoms. Finally, we employed binary logistic regression analysis to explore the association between exposure variables and unhealthy symptoms. Binary logistic regression is appropriate since each unhealthy symptom was measured in 2 categories. In model 1 (unadjusted model), we considered 3 indoor house pollution exposure variables. In model 2 (adjusted model), we additionally considered the remaining variables as control variables. The results of these models were reported using Odds Ratios (OR). The statistical analyses were done in Stata version 16.

Results

Table 1 presents the descriptive characteristics of the study variables. The mean age of the study participants was around 60 years, with a standard deviation of 10.66. It was found that more than 52% of households used clean cooking fuel among the study population, and about 75% did not have a member who smoked inside the house. More than 88% of households use incense inside their homes. Nearly 50% of the study participants were employed, and about 10% reported work-limiting health conditions. Among the study participants, 15.15% had ever consumed alcohol, and 32.70% were current smokers. It was found that most study participants hardly or never engaged in physical activities (58.46%). Based on health-related indicators, it was revealed that 18.49%, 16.34%, and 36.80% of the study participants reported poor SRH status, low ADL, and low IADL statuses, respectively. Based on the socioeconomic and demographic status of the study participants, it was found that about 53.94% were female, and around 51% had no formal schooling. Around 45% of middle-aged and older adults were from OBC social class backgrounds. Most of the study participants were from rural areas (69.72%).

Table 2 shows the result of bivariate analysis on the prevalence of unhealthy symptoms with baseline characteristics. The results showed that 7.50%, 13.56%, 12.12%, 21.98%, 5.49%, and 8.12% of the study participants had shortness of breath, dizziness, headache, fatigue, wheezing, and cough, respectively. The results indicated that middle-aged and older adults from those households that used solid cooking fuel compared to clean cooking fuel had a significantly higher prevalence of shortness of breath (8.01% vs 7.04%), dizziness (16.65% vs 10.72%), headache (12.96% vs 11.35%), fatigue (25.55% vs 18.71%), wheezing (6.88% vs 4.22%), and cough (9.71% vs 6.66).

The result also indicated that there exists a significantly high prevalence of shortness of breath (8.62% vs 7.13%), dizziness (14.39% vs 13.28%), headache (12.93% vs 11.85%), fatigue (22.83% vs 21.70%), wheezing (6.75% vs 5.07%), and cough (10.95% vs 7.17%) among those from households with a member who smokes inside the house in comparison to those with no household member who smokes inside the house. The results showed that in comparison with individuals from a household where no incense was used, the prevalence of shortness of breath (7.32% vs 8.93%), dizziness (13.55% vs 13.62%), headache (11.98% vs 13.18%), wheezing (5.27% vs 7.17%), and cough (7.85% vs 10.16%) was significantly lower in those participants from households where any incense was used. The prevalence of unhealthy conditions with exposure variables is presented separately in Figures 2 to 7.

Tables 3 and 4 presents the results of logistic regression models for shortness of breath, dizziness, headache, fatigue, wheezing, and cough by the baseline characteristics of the

Table 1. Descriptive characteristics of the study variables.

VARIABLES	FREQUENCY	WEIGHTED PERCENTAGE
Type of cooking fuel		
Clean	34 596	52.16
Solid	29 194	47.84
Do anyone smoke inside the home		
No	47 736	74.93
Yes	16 054	25.07
Use of incense inside the home		
No	10 359	11.70
Yes	53 431	88.30
Current work status		
Never worked	1330	1.45
Homemaker	16 467	24.19
Currently not working	16 509	27.22
Currently working	29 484	47.14
Work-limiting health conditions		
No	25 688	39.25
Yes	4824	9.64
Others/Not working	33 278	51.11
Alcohol consumption		
Never	52 373	84.85
Ever	11 417	15.15
Smoking status		
Never	4530	62.48
Quit	3476	4.82
Currently smoking	19 784	32.70
Physical activities		
Everyday	15 290	25.48
More than once a week	4473	6.77
Once a week	2348	3.72
One-three times a month	3197	5.57
Hardly ever or never	38 482	58.46
Self-rated health (SRH)		
Good	53 015	81.51
Poor	10 775	18.49

(Continued)

Table 1. (Continued)

VARIABLES	FREQUENCY	WEIGHTED PERCENTAGE
Activities of daily living (ADL)		
High	54726	83.66
Low	8964	16.34
Instrumental activities of daily living		
High	42908	63.20
Low	20882	36.80
Mean age in years (SD)	60.15 (10.66)	
Gender		
Female	34102	53.94
Male	29688	46.06
Education		
No schooling	29972	50.68
1-5 y	11674	17.51
6-10 y	15413	21.07
Above 10 y	6731	10.74
Household economic status		
Poorest	12354	20.86
Poorer	12868	21.34
Middle	12855	20.25
Richer	12903	19.40
Richest	12808	18.15
Social class		
Scheduled tribe (ST)	11201	8.92
Scheduled caste (SC)	10727	19.67
Other backward class (OBC)	24256	44.82
Others	17606	26.59
Residence type		
Urban	22162	30.28
Rural	41628	69.72
Total sample	63790	100

Abbreviation: SD, standard deviation.

study participants. The unadjusted models (Model 1) and the adjusted model (Model 2) are also presented. The results revealed that in comparison with those study participants from the households where clean cooking fuel was used, those from households where they used solid cooking fuel had higher odds of shortness of breath (adjusted OR: 1.14, 99% CI: 1.05-1.23), dizziness (adjusted OR: 1.28, 99% CI: 1.21-1.35), fatigue (adjusted OR: 1.32, 99% CI: 1.26-1.39), wheezing (adjusted OR: 1.30, 99% CI: 1.19-1.42), and cough (adjusted OR: 1.36, 99% CI: 1.27-1.45). Similarly, it was found that those study participants from households with a smoker inside had a higher odds of shortness of breath (adjusted OR: 1.28, 99% CI: 1.19-1.38), headache (adjusted OR: 1.14, 99% CI: 1.08-1.21), wheezing (adjusted OR: 1.33, 99% CI: 1.22-1.45), and cough (adjusted OR: 1.23, 99% CI: 1.16-1.31). The results also indicated that those study participants from households where incense was used had higher odds of fatigue than those from households where incense was not used (adjusted OR: 1.21, 99% CI: 1.14-1.29). On the contrary, it was found that study participants from households where incense was used had a lower odds of shortness of breath (adjusted OR: 0.86, 99% CI: 0.79-0.94), headache (adjusted OR: 0.85, 99% CI: 0.79-0.90), and cough (adjusted OR: 0.67, 99% CI: 0.63-0.72) compared to those individuals from households where incenses were not used.

Among the control variables, it was found that compared to never worked study participants, those who were not working at the time of the interview were significantly more likely to report shortness of breath (adjusted OR: 1.41, 99% CI: 1.12-1.78), dizziness (adjusted OR: 1.58, 95% CI: 1.31-1.90), fatigue (adjusted OR: 1.86, 99% CI: 1.57-2.21), cough (adjusted OR: 1.28, 99% CI: 1.06-1.55). The results also revealed that homemakers were significantly more likely to report fatigue and cough than participants who had never worked. It was further indicated that compared to older adults who never worked, those working had significantly higher odds of dizziness and fatigue. In contrast, they had lower odds of headaches. In line with the expectation, in general, the results indicated that older adults who were not working and those who reported any work-limiting health conditions were significantly more likely to report all major unhealthy symptoms. Based on the health behavior variables, it was revealed that in comparison with never-smokers, those who quit smoking and current smokers had significantly higher odds of reporting all the unhealthy symptoms. Contrastingly, individuals who ever consumed alcohol had higher odds of cough but lower odds of fatigue and headache compared to their counterparts. The results showed that compared to those who engaged in everyday physical activities, those with a lower frequency of physical activities were more likely to report unhealthy symptoms.

Based on the health-related factors, the results showed that older adults with poor SRH had higher odds of shortness of breath (adjusted OR: 2.11, 99% CI: 1.96-2.27), dizziness (adjusted OR: 1.82, 99% CI: 1.72-1.93), headache (adjusted OR: 1.68, 99% CI: 1.58-1.78), fatigue (adjusted OR: 1.94, 99% CI: 1.85-2.04), wheezing (adjusted OR: 2.18, 99% CI: 2.00-2.36), and cough (adjusted OR: 1.78, 99% CI: 1.67-1.90) in comparison with those who reported good SRH. Similarly, the findings revealed that older adults

Table 2. Bivariate Analysis of the prevalence of unhealthy symptoms with baseline characteristics.

	SHORTNESS OF BREATH	*P* VALUE	DIZZINESS	*P* VALUE	HEADACHE	*P* VALUE	FATIGUE	*P* VALUE	WHEEZING	*P* VALUE	COUGH	*P* VALUE
Type of cooking fuel												
Clean	7.04	.00	10.72	.00	11.35	.00	18.71	.00	4.22	.00	6.66	.00
Solid	8.01		16.65		12.96		25.55		6.88		9.71	
Do anyone smoke inside the home												
No	7.13	.00	13.28	.00	11.85	.00	21.70	.00	5.07	.00	7.17	.00
Yes	8.62		14.39		12.93		22.83		6.75		10.95	
Use of incense inside the home												
No	8.93	.00	13.62	.00	13.18	.00	21.88	.00	7.17	.76	10.16	.00
Yes	7.32		13.55		11.98		22.00		5.27		7.85	
Current work status												
Never Worked	6.95	.00	12.42	.00	11.50	.00	16.90	.00	9.87	.00	11.05	.00
Homemaker	8.55		15.43		13.70		24.41		5.68		7.01	
Currently not working	10.66		15.24		13.49		25.20		7.51		10.85	
Currently working	5.16		11.67		10.54		19.04		4.09		7.02	
Work-limiting health conditions												
No	4.07	.00	10.15	.00	9.44	.00	16.16	.00	3.58	.00	6.40	.00
Yes	11.11		18.60		16.46		33.81		6.99		10.02	
Others/Not working	9.46		15.22		13.36		24.23		6.67		9.08	
Alcohol consumption												
Never	7.58	.46	13.87	.00	12.74	.00	22.54	.00	5.37	.04	7.49	.00
Ever	7.07		11.80		8.63		18.90		6.18		11.67	
Smoking status												
Never	6.93	.00	13.01	.00	12.61	.00	21.36	.00	4.94	.00	6.16	.00
Quit	11.23		15.60		13.47		25.39		10.02		13.06	
Currently smoking	8.06		14.30		10.99		22.68		5.88		11.14	

(Continued)

Table 2. (Continued)

	SHORTNESS OF BREATH	*P* VALUE	DIZZINESS	*P* VALUE	HEADACHE	*P* VALUE	FATIGUE	*P* VALUE	WHEEZING	*P* VALUE	COUGH	*P* VALUE
Physical activities												
Everyday	5.67	.00	10.51	.00	11.42	.00	18.37	.00	3.67	.00	7.38	.00
More than once a week	6.81		14.06		12.69		21.98		6.48		9.10	
Once a week	7.03		16.10		12.10		21.14		6.38		7.36	
One-three times a month	7.34		16.80		12.69		25.77		7.26		9.88	
Hardly ever or never	8.43		14.36		12.31		23.25		5.94		8.21	
Self-rated health (SRH)												
Good	5.71	.00	11.42	.00	10.76	.00	18.96	.00	4.20	.00	6.80	.00
Poor	15.41		23.98		18.10		35.32		11.17		13.94	
Activities of daily living (ADL)												
High	5.99	.00	11.82	.00	10.78	.00	19.06	.00	4.57	.00	7.51	.00
Low	15.26		22.48		19.00		36.97		10.12		11.23	
Instrumental activities of daily living												
High	5.23	.00	10.71	.00	9.51	.00	17.40	.00	3.84	.00	6.92	.00
Low	11.41		18.45		16.61		29.85		8.32		10.17	
Gender												
Female	8.28	.00	16.58	.00	15.73	.00	24.54	.00	5.18	.72	6.46	.00
Male	6.59		10.02		7.90		18.99		5.85		10.07	
Education												
No schooling	8.43	.00	16.21	.00	14.67	.00	24.67	.00	6.15	.00	8.48	.00
1-5 y	8.12		15.20		12.42		23.66		6.73		9.03	
6-10 y	6.64		9.79		8.84		17.89		4.13		7.24	
Above 10 y	3.80		5.75		6.03		14.59		3.01		6.67	

(Continued)

Table 2. (Continued)

	SHORTNESS OF BREATH	*P* VALUE	DIZZINESS	*P* VALUE	HEADACHE	*P* VALUE	FATIGUE	*P* VALUE	WHEEZING	*P* VALUE	COUGH	*P* VALUE
Household economic status												
Poorest	6.66	.00	13.28	.17	11.20	.00	21.32	.39	4.50	.00	7.50	.00
Poorer	6.69		14.57		12.28		22.94		6.20		8.38	
Middle	7.21		13.35		11.71		21.11		5.28		8.41	
Richer	7.87		13.15		12.78		21.69		6.34		7.59	
Richest	9.37		13.37		12.74		22.92		5.12		8.77	
Social class												
Scheduled tribe (ST)	8.05	.00	17.96	.00	11.81	.04	22.95	.00	6.08	.00	8.61	.00
Scheduled caste (SC)	8.22		15.18		12.28		24.94		6.48		8.29	
Other backward class (OBC)	7.02		12.57		12.16		20.81		5.10		8.09	
Others	7.61		12.55		12.04		21.45		5.21		7.87	
Residence type												
Urban	7.07	.00	9.84	.00	9.86	.00	19.42	.00	3.96	.00	6.67	.00
Rural	7.69		15.18		13.10		23.10		6.15		8.75	
Prevalence of unhealthy conditions in percentage	7.50		13.56		12.12		21.98		5.49		8.12	

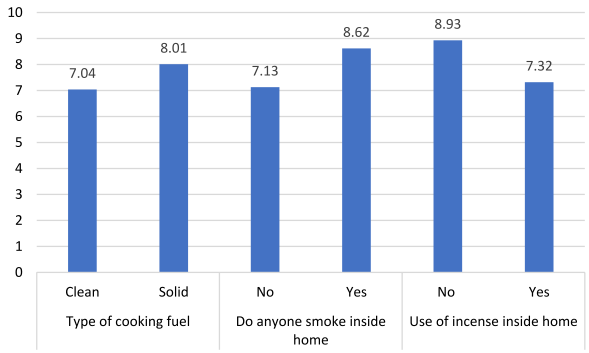

Figure 2. Percentage prevalence of shortness of breath by indoor pollution characteristics.

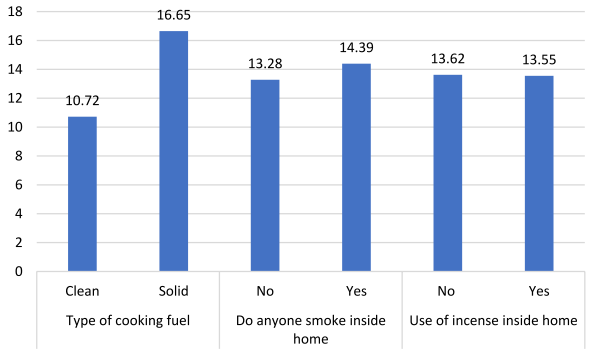

Figure 3. Percentage prevalence of dizziness by indoor pollution characteristics.

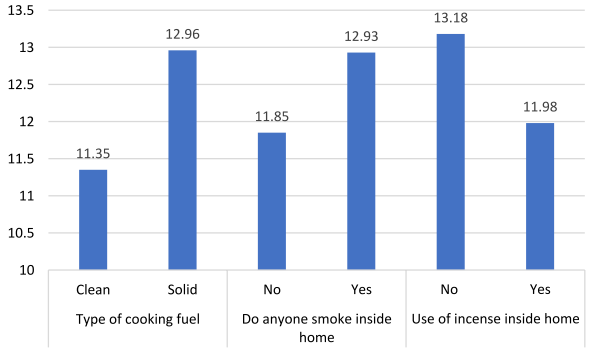

Figure 4. Percentage prevalence of headache by indoor pollution characteristics.

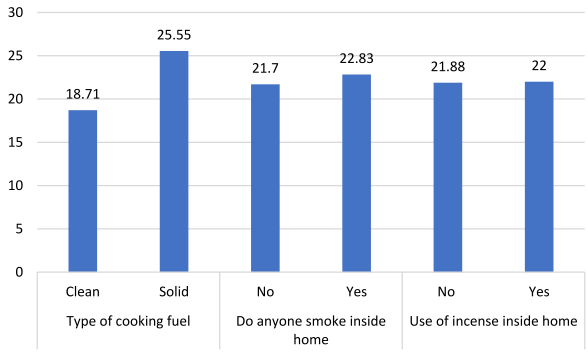

Figure 5. Percentage prevalence of fatigue by indoor pollution characteristics.

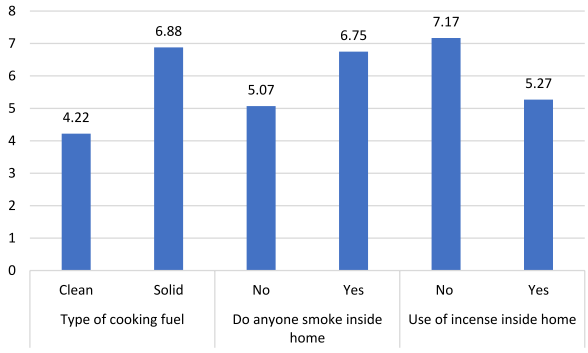

Figure 6. Percentage prevalence of wheezing by indoor pollution characteristics.

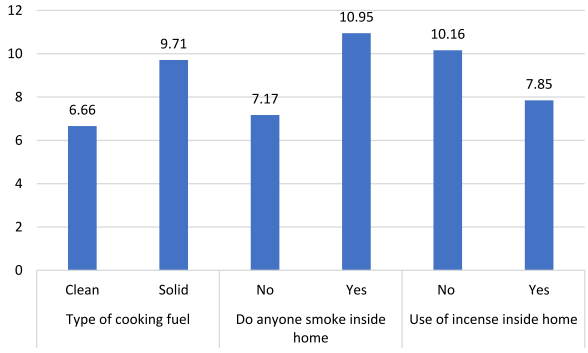

Figure 7. Percentage prevalence of cough by indoor pollution characteristics.

with low ADL and low IADL had significantly higher odds of reporting all 6 unhealthy symptoms in comparison with those who reported high ADL and high IADL, respectively. In conjunction with expectations, the risk of shortness of breath, dizziness, headache, fatigue, and cough significantly increased with age. The results indicated that male older adults had significantly lower odds of reporting dizziness (adjusted OR: 0.53, 99% CI: 0.49-0.56), headache (adjusted OR: 0.53, 99% CI: 0.49-0.56), fatigue (adjusted OR: 0.74, 99% CI: 0.70-0.78), and a higher odds of wheezing (adjusted OR: 1.23, 99% CI: 1.11-1.36) and cough (adjusted OR: 1.25, 99% CI: 1.16-1.34). Overall, it was found that those participants with more years of education had significantly lower odds of shortness of breath, dizziness, headache, fatigue, and wheezing. On the contrary to expectation, it was found that older adults from higher economic status were significantly more likely to report unhealthy symptoms. The results also showed that in comparison with urban residents, rural residents had significantly higher odds of dizziness (adjusted OR: 1.10, 99% CI: 1.04-1.17), headache

Table 3. Results of logistic regression analysis for shortness of breath, dizziness and headache with baseline characteristics.

	SHORTNESS OF BREATH		DIZZINESS		HEADACHE	
	MODEL 1	MODEL 2	MODEL 1	MODEL 2	MODEL 1	MODEL 2
	UNADJUSTED ODDS RATIO (95% CI)	ADJUSTED ODDS RATIO (95% CI)	UNADJUSTED ODDS RATIO (95% CI)	ADJUSTED ODDS RATIO (95% CI)	UNADJUSTED ODDS RATIO (95% CI)	ADJUSTED ODDS RATIO (95% CI)
Type of cooking fuel (Ref: Clean)						
Solid	1.25*** (1.17-1.33)	1.14*** (1.05-1.23)	1.57*** (1.50-1.65)	1.28*** (1.21-1.35)	1.13*** (1.07-1.18)	0.97 (0.92-1.03)
Do anyone smoke inside the home (Ref: No)						
Yes	1.31*** (1.23-1.41)	1.28*** (1.19-1.38)	1.04 (0.99-1.10)	0.96 (0.91-1.02)	1.16*** (1.10-1.23)	1.14*** (1.08-1.21)
Use of incense inside the home (Ref: No)						
Yes	0.90** (0.83-0.98)	0.86*** (0.79-0.94)	0.92*** (0.87-0.98)	0.96 (0.90-1.02)	0.86*** (0.81-0.92)	0.85*** (0.79-0.90)
Current work status (Ref: Never worked)						
Homemaker		1.21 (0.96-1.53)		1.22** (1.01-1.47)		0.89 (0.75-1.05)
Currently not working		1.41*** (1.12-1.78)		1.58*** (1.31-1.90)		1.02 (0.86-1.21)
Currently working		0.97 (0.74-1.28)		1.41*** (1.13-1.76)		0.83* (0.67-1.02)
Work-limiting health conditions (Ref: No)						
Yes		2.09*** (1.86-2.34)		1.53*** (1.40-1.67)		1.75*** (1.60-1.91)
Others/Not working		1.24*** (1.06-1.46)		1.16** (1.02-1.32)		1.03 (0.90-1.17)
Alcohol consumption (Ref: Never)						
Ever		0.95 (0.86-1.04)		0.97 (0.90-1.04)		0.92** (0.85-0.99)
Smoking status (Ref: Never)						
Quit smoking		1.51*** (1.33-1.72)		1.30*** (1.16-1.44)		1.12** (1.00-1.26)
Currently smoking		1.15*** (1.06-1.25)		1.34*** (1.26-1.42)		1.09** (1.02-1.15)
Physical activities (Ref: Everyday)						
More than once a week		1.03 (0.89-1.20)		1.39*** (1.27-1.53)		1.09 (0.98-1.21)
Once a week		1.07 (0.89-1.28)		1.34*** (1.18-1.52)		1.08 (0.95-1.23)
One-three times a month		1.17** (1.00-1.37)		1.29*** (1.16-1.44)		1.11* (0.99-1.25)
Hardly ever or never		0.93 (0.85-1.02)		0.91*** (0.85-0.97)		0.89*** (0.84-0.96)

(Continued)

Table 3. (Continued)

	SHORTNESS OF BREATH		DIZZINESS		HEADACHE	
	MODEL 1	MODEL 2	MODEL 1	MODEL 2	MODEL 1	MODEL 2
	UNADJUSTED ODDS RATIO (95% CI)	ADJUSTED ODDS RATIO (95% CI)	UNADJUSTED ODDS RATIO (95% CI)	ADJUSTED ODDS RATIO (95% CI)	UNADJUSTED ODDS RATIO (95% CI)	ADJUSTED ODDS RATIO (95% CI)
Self-rated health (SRH) (Ref: Good)						
Poor		2.11*** (1.96-2.27)		1.82*** (1.72-1.93)		1.68*** (1.58-1.78)
Activities of daily living (ADL) (Ref: High)						
Low		1.80*** (1.66-1.95)		1.39*** (1.30-1.48)		1.42*** (1.32-1.52)
Instrumental activities of daily living (IADL) (Ref: High)						
Low		1.29*** (1.19-1.39)		1.24*** (1.17-1.31)		1.35*** (1.28-1.43)
Age in years		1.00*** (1.00-1.01)		1.00* (1.00-1.00)		0.99*** (0.98-0.99)
Gender (Ref: Female)						
Male		0.98 (0.90-1.07)		0.53*** (0.49-0.56)		0.53*** (0.49-0.56)
Education (Ref: No schooling)						
1-5 y		0.96 (0.88-1.05)		1.10*** (1.03-1.18)		0.96 (0.90-1.03)
6-10 y		0.77*** (0.70-0.84)		0.91*** (0.84-0.97)		0.80*** (0.75-0.86)
More than 10 y		0.58*** (0.50-0.68)		0.63*** (0.56-0.71)		0.60*** (0.54-0.68)
Household economic status (Ref: Poorest)						
Poorer		1.13** (1.01-1.26)		1.16*** (1.08-1.25)		1.22*** (1.13-1.32)
Middle		1.16*** (1.04-1.29)		1.16*** (1.07-1.25)		1.24*** (1.14-1.34)
Richer		1.34*** (1.21-1.49)		1.21*** (1.12-1.31)		1.40*** (1.29-1.52)
Richest		1.60*** (1.44-1.78)		1.37*** (1.27-1.48)		1.58*** (1.45-1.71)
Social class (Ref: Scheduled Tribe (ST))						
Scheduled caste (SC)		1.08 (0.97-1.21)		0.70*** (0.65-0.76)		0.87*** (0.80-0.94)
Other backward class (OBC)		1.01 (0.91-1.12)		0.71*** (0.67-0.76)		0.90*** (0.84-0.97)
Others		1.11* (0.99-1.23)		0.74*** (0.69-0.80)		0.91** (0.84-0.99)
Residence type (Ref: Urban)						
Rural		1.06 (0.98-1.15)		1.10*** (1.04-1.17)		1.13*** (1.06-1.20)
Constant	0.06*** (0.06-0.07)	0.02*** (0.01-0.03)	0.13*** (0.12-0.14)	0.10*** (0.08-0.13)	0.15*** (0.14-0.15)	0.33*** (0.25-0.43)
Sample	63790	63790	63790	63790	63790	63790

Confidence intervals in parentheses.
***$P < .01$. **$P < .05$. *$P < .10$.

Table 4. Results of logistic regression analysis for fatigue, wheezing, and cough with baseline characteristics.

	FATIGUE		WHEEZING		COUGH	
	MODEL 1	MODEL 2	MODEL 1	MODEL 2	MODEL 1	MODEL 2
	UNADJUSTED ODDS RATIO (95% CI)	ADJUSTED ODDS RATIO (95% CI)	UNADJUSTED ODDS RATIO (95% CI)	ADJUSTED ODDS RATIO (95% CI)	ADJUSTED ODDS RATIO (95% CI)	ADJUSTED ODDS RATIO (95% CI)
Type of cooking fuel (Ref: Clean)						
Solid	1.43*** (1.38-1.49)	1.32*** (1.26-1.39)	1.42*** (1.32-1.52)	1.30*** (1.19-1.42)	1.50*** (1.42-1.58)	1.36*** (1.27-1.45)
Do anyone smoke inside the home (Ref: No)						
Yes	1.09*** (1.05-1.14)	1.03 (0.98-1.08)	1.37*** (1.27-1.48)	1.33*** (1.22-1.45)	1.37*** (1.29-1.45)	1.23*** (1.16-1.31)
Use of incense inside the home (Ref: No)						
Yes	1.33*** (1.25-1.40)	1.21*** (1.14-1.29)	1.08 (0.98-1.19)	0.98 (0.88-1.08)	0.61*** (0.57-0.65)	0.67*** (0.63-0.72)
Current work status (Ref: Never worked)						
Homemaker		1.78*** (1.50-2.12)		1.11 (0.87-1.44)		1.24** (1.02-1.50)
Currently not working		1.86*** (1.57-2.21)		1.10 (0.85-1.40)		1.28*** (1.06-1.55)
Currently working		1.92*** (1.57-2.34)		0.82 (0.61-1.11)		1.01 (0.81-1.28)
Work-limiting health conditions (Ref: No)						
Yes		1.96*** (1.82-2.11)		1.58*** (1.38-1.80)		1.25*** (1.13-1.39)
Others/Not working		1.29*** (1.15-1.44)		1.17* (0.98-1.41)		1.15* (1.00-1.32)
Alcohol consumption (Ref: Never)						
Ever		0.93** (0.88-0.99)		1.02 (0.91-1.13)		1.10*** (1.03-1.19)
Smoking status (Ref: Never)						
Quit smoking		1.28*** (1.16-1.40)		1.45*** (1.25-1.67)		1.63*** (1.46-1.81)
Currently smoking		1.29*** (1.22-1.36)		1.07 (0.98-1.18)		1.37*** (1.28-1.46)
Physical activities (Ref: Everyday)						
More than once a week		1.19*** (1.09-1.30)		1.20** (1.02-1.41)		1.20*** (1.08-1.33)
Once a week		1.17*** (1.04-1.31)		1.18 (0.97-1.45)		0.99 (0.86-1.14)
1-3 times a month		1.35*** (1.23-1.49)		1.46*** (1.24-1.72)		1.09 (0.96-1.24)
Hardly ever or never		0.99 (0.93-1.05)		0.94 (0.84-1.04)		0.78*** (0.73-0.84)

(Continued)

Table 4. (Continued)

	FATIGUE		WHEEZING		COUGH	
	MODEL 1	MODEL 2	MODEL 1	MODEL 2	MODEL 1	MODEL 2
	UNADJUSTED ODDS RATIO (95% CI)	ADJUSTED ODDS RATIO (95% CI)	UNADJUSTED ODDS RATIO (95% CI)	ADJUSTED ODDS RATIO (95% CI)	ADJUSTED ODDS RATIO (95% CI)	ADJUSTED ODDS RATIO (95% CI)
Self-rated health (SRH) (Ref: Good)						
Poor		1.94*** (1.85-2.04)		2.18*** (2.00-2.36)		1.78*** (1.67-1.90)
Activities of daily living (ADL) (Ref: High)						
Low		1.49*** (1.41-1.58)		1.49*** (1.36-1.64)		1.12*** (1.03-1.21)
Instrumental activities of daily living (IADL) (Ref: High)						
Low		1.60*** (1.53-1.68)		1.50*** (1.38-1.64)		1.18*** (1.11-1.26)
Age in years		1.00* (1.00-1.00)		1.00 (1.00-1.01)		1.02*** (1.01-1.02)
Gender (Ref: Female)						
Male		0.74*** (0.70-0.78)		1.23*** (1.11-1.36)		1.25*** (1.16-1.34)
Education (Ref: No schooling)						
1-5 y		1.08*** (1.02-1.14)		1.06 (0.96-1.16)		1.09** (1.01-1.17)
6-10 y		0.96 (0.91-1.02)		0.82*** (0.74-0.91)		1.13*** (1.05-1.21)
More than 10 y		0.83*** (0.76-0.90)		0.68*** (0.58-0.81)		0.82*** (0.72-0.92)
Household economic status (Ref: Poorest)						
Poorer		1.07** (1.00-1.14)		1.31*** (1.16-1.48)		1.24*** (1.13-1.35)
Middle		1.05 (0.99-1.13)		1.27*** (1.13-1.44)		1.34*** (1.23-1.46)
Richer		1.11*** (1.03-1.18)		1.50*** (1.33-1.69)		1.39*** (1.27-1.51)
Richest		1.12*** (1.05-1.20)		1.42*** (1.25-1.61)		1.60*** (1.46-1.75)
Social class (Ref: Scheduled tribe (ST))						
Scheduled caste (SC)		1.27*** (1.18-1.36)		1.45*** (1.27-1.66)		0.55*** (0.50-0.60)
Other backward class (OBC)		1.16*** (1.08-1.24)		1.33*** (1.18-1.50)		0.57*** (0.53-0.62)
Others		1.33*** (1.24-1.43)		1.36*** (1.20-1.55)		0.62*** (0.57-0.67)
Residence type (Ref: Urban)						
Rural		1.02 (0.97-1.07)		1.11** (1.01-1.22)		1.01 (0.94-1.08)
Constant	0.15*** (0.15-0.16)	0.04*** (0.03-0.05)	0.04*** (0.03-0.04)	0.01*** (0.01-0.02)	0.12*** (0.12-0.13)	0.03*** (0.02-0.04)
Sample	63 790	63 790	63 790	63 790	63 790	63 790

Confidence intervals in parentheses.
***$P < .01$. **$P < .05$, *$P < .10$.

(adjusted OR: 1.13, 99% CI: 1.06-1.20), and wheezing (adjusted OR: 1.11, 95% CI: 1.01-1.22).

Discussion

The present study tried to understand the association between indoor air pollution and unhealthy symptoms among India's middle-aged and older adult population. It is evident from this study's results that the use of solid cooking fuels significantly increased the odds of shortness of breath, dizziness, fatigue, and cough. Similar to these results, a study conducted in rural West Bengal, India, suggested that the use of biomass as a fuel led to a high prevalence of shortness of breath, cough, eye irritation, and dizziness and a strong positive association between diastolic and systolic pressure among biomass users, while wood as fuel users had high systolic pressure.[26] In addition, another study also reported a high prevalence of dry cough.[27]

The results of the present study also evidenced that smokers inside the house increased the odds of shortness of breath, headache, wheezing, and cough. Although very few studies have been done in this context, to our knowledge, studies have identified smoking as a source of indoor pollution[4] and has been associated with depression among women.[28] Interestingly, using incense in households reduced the unhealthy symptoms except for fatigue. This positive effect could be due to the religious and cultural underpinning associated with the use of incense, and religious beliefs may elevate the mood, leading to reduced unhealthy symptoms. However, the literature points to health risks associated with indoor incense use.[29-31]

Regarding working status, individuals who stopped working had higher odds of shortness of breath, dizziness, fatigue, and cough than those who never worked. To our knowledge, no earlier studies have considered the impact of work status on specific symptoms. However, earlier studies pointed to the impact of unemployment on mental and physical health,[32,33] which might pave the way for unhealthy symptoms. Also, the present study evidenced that unhealthy symptoms were prevalent among homemakers. This could be because people spend more time in the house, where exposure to indoor air pollution is higher. In support of this, a study conducted in rural China among female homemakers found unhealthy biomarkers, increased inflammatory reactions, and oxidative stress in solid fuel burners.[34]

This study's results also showed unhealthy behaviors, as smoking and alcohol consumption increased the odds of major unhealthy symptoms. These results are supported by an earlier study showing that smoking cessation led to a lower risk of cardiovascular diseases, although former smokers face a higher risk of these diseases compared to those who have never smoked.[35] Moreover, quitting smoking still improves health outcomes.[36] Contrastingly, in the case of alcohol consumption, a meta-analysis found a high to moderate risk of bias, and no association was identified between alcohol consumption and tension-related headaches.[37] In line with the results of the present study, engagement in physical activities was positively associated with good physical and mental health. It was a protective factor against chronic health conditions.[38]

We also identified higher odds of unhealthy symptoms among individuals with poor SRH, low ADL, and IADL compared to their counterparts in this study. These results are consistent with earlier studies indicating the association between poor SRH and fatigue.[39] There exists a relationship between poor functionality (low ADL and low IADL) with SRH[40] and mortality,[41] which could be attributed to unhealthy symptoms, as these may suggest underlying diseases or health conditions.

In addition, the inclination to unhealthy symptoms increased with age, being male, lower years of education, and rural residence. The functional deterioration at age[42] is well-established and might pave the way for unhealthy symptoms. Also, evidence suggests that gender differences exist in health[43] and education plays an essential role in health outcomes,[44] indicating the role of these factors on health. Similarly, individuals in rural residences may have higher exposure to the combustion of solid fuels, which could initiate and increase the unhealthy symptoms. A study conducted among rural women showed that about 63.8% of houses did not have a proper smoke outlet while using solid cooking fuels in Southern India.[45] Contrasting to the expectations, in this study, individuals with high socioeconomic status had higher odds of unhealthy symptoms. This could be attributed to the disease of affluence.[46] However, an earlier study in the UK suggested that low economic status was associated with a higher risk of common diseases.[47]

Limitations

Though this study is the first in India to explore the association between indoor air pollution and unhealthy symptoms, it has some limitations. Firstly, the study did not establish a causal association between the variables due to its cross-sectional nature. Since LASI expects to be a prospective study, future studies can better demonstrate the cause and effect association between variables with the advantage of a longitudinal approach. Secondly, the study uses self-reported measures, although reliability firmly exists, it may pertain to report and recall biases. Thirdly, no biological tests are conducted to evaluate the degree of unhealthy symptoms considered in this study.

Conclusion

The present study tried to understand the association between sources of indoor air pollution and unhealthy symptoms, including shortness of breath, dizziness, headache, fatigue, wheezing, and cough. It is evident from the study results that the use of solid cooking fuels and having someone smoke inside the house lead to higher odds of these unhealthy symptoms. Interestingly, using incense reduced the odds of unhealthy symptoms except for fatigue. Further, in general, the results indicate that working status, being a homemaker, having work-limiting health conditions, smoking, alcohol consumption, age, being male, low education level, high economic status, and rural residence were associated with higher

unhealthy symptoms. However, involvement in physical activity played a protective role from unhealthy symptoms.

It is essential to develop programs to combat the sources of indoor air pollution and these symptoms, especially in rural settings, as they may pave the way for chronic diseases or indicate existing health conditions. We also suggest policy-level changes to raise awareness and encourage the practice of clean fuel usage, especially in rural locales. The government, especially the local self-government and primary healthcare centers, should initiate community-level programs to sensitize the people about the adverse health outcomes of solid cooking fuel usage. This is crucial because studies have documented that lack of awareness contributes to using unclean fuel for cooking.[48] Moreover, specifically in the Indian context, access to government programs promoting Liquid Petroleum Gas, like Ujjwala Yojana, should be universally made available to rural and marginalized communities. Also, it is important to identify individuals with unhealthy symptoms, and they should be well-informed about the potential causes, including the use of solid fuels, so that health services may facilitate early diagnosis and interventions. Public health professionals and physicians may consider these contexts of solid cooking fuel use and unhealthy symptoms while working with populations from rural communities and localities vulnerable to indoor air pollution. So, they may intervene to reduce indoor air pollution exposure and address these symptoms accordingly.

Evidence exists on the success of systematic interventions to reduce the adverse effects of indoor air pollution on health.[49] Such locally relevant interventions can be initiated to sensitize communities about the potential risks of solid cooking fuels and promote clean fuel usage. Future studies can focus on longitudinal designs utilizing biomarkers to document the cause and effect of solid cooking fuels and health outcomes. Also, studies can determine the attitudinal and sociocultural aspects contributing to the usage of solid cooking fuels.

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Authors' Contributions
CV and EP conceptualized and supervised. CV was involved in the data analysis. PP wrote the main manuscript. Critical revision of the manuscript for intellectual content: EP and AP. All authors read and approved the final draft.

Ethics Approval and Consent to Participate
Ethical approval for conducting the Longitudinal Aging Study in India (LASI) was guided by the Indian Council of Medical Research. The secondary data used for this study is freely available in the public domain. Hence, no third-party ethical clearance was sought for this study.

Consent for Publication
Not applicable.

Availability of Data and Materials
The data used for this study is available through the following website. https://www.iipsindia.ac.in/content/lasi-wave-i or through https://g2aging.org/.

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