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Case–control study of indoor cooking smoke exposure and cataract in Nepal and India

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Background The prevalence of cataract is higher in developing countries, and in both developed and developing countries more females than males are blind from cataracts. Three epidemiological studies have associated indoor cooking with solid fuels (e.g. wood or dung) and cataract or blindness. However, associations in these studies may have been caused by unmeasured confounding.

Methods A hospital-based case–control study was conducted on the Nepal–India border. Cases ($n = 206$) were women patients, aged 35–75 years with confirmed cataracts. Controls ($n = 203$), frequency matched by age, were patients attending the refractive error clinic at the same hospital. A standardized questionnaire was administered to all participants. Logistic regression analysis involved adjustment for age, literacy, residential area, ventilation, type of lighting, incense use, and working outside.

Results Compared with using a clean-burning-fuel stove (biogas, LPG, or kerosene), the adjusted odds ratio (OR) for using a flued solid-fuel stove was 1.23 [95% confidence interval (CI) 0.44–3.42], whereas use of an unflued solid-fuel stove had an OR of 1.90 (95% CI 1.00–3.61). Lack of kitchen ventilation was an independent risk factor for cataract (OR 1.96; 95% CI 1.25–3.07).

Conclusion This study provides confirmatory evidence that use of solid fuel in unflued indoor stoves is associated with increased risk of cataract in women who do the cooking. The association is not likely to be due to bias, including confounding, and strengthens the findings of three previous studies. Replacing unflued stoves with flued stoves would greatly reduce this risk, although cooking with cleaner-burning fuels would be the best option.

Keywords Case–control studies, cataract, India, indoor air pollution, Nepal

Annually, about 2 million people become blind worldwide and cataract-related blindness accounts for half of these cases.[1,2] The prevalence of cataract is higher in females than in males in developed and developing countries,[3,4] and in developing countries cataract occurs at an earlier age.[2] Epidemiological studies have established certain risk factors for cataract formation, particularly age, exposure to UV-B radiation (sunlight),[5–14] cigarette smoking,[13,15–19] diabetes,[20–22] severe diarrhoea and malnutrition,[23–25] lower socioeconomic status, lower education, and occupation.[26–30] However, understanding of risk factors and biochemical and structural events leading to the formation of cataract is incomplete.[31]

Three epidemiological studies have provided some evidence of an association between cataract or blindness and exposure to indoor smoke from household use of solid biomass fuels, such as animal dung, wood, and crop residues.[26,32,33] However, these studies have had limitations that have precluded establishment of a definitive causal relationship. The first study to find an association between cataract and indoor smoke exposure, by Mohan *et al.*, was not specifically investigating this association and regarded it as an incidental finding likely to have been a result of confounding by socioeconomic factors.[26] The second case–control study, by Zodpey and Ughade,[33] which also found an association between cataract and cheaper cooking fuels (coal, cow dung, and wood), presented limited data on potential confounding factors, other than age and

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socioeconomic status. In particular, there was no information on kitchen characteristics or ventilation, dietary habits/practices, history of diarrhoea, exposure to sunlight, or smoking habits, which might confound the relationship. The third study, with a cross-sectional design, used data from the 1992–93 Indian National Family Health Survey. This study found an association between biomass fuel use and partial and complete blindness after adjustment for a number of potentially confounding factors.[32] Information was not available on smoking or on type of blindness, which was determined through self-reporting.

To further investigate the possible relationship of cataract formation with indoor smoke exposure, we conducted a cataract case–control study in the area of the Nepal–India border where cooking with solid fuels in unvented indoor stoves is a common practice. The main objectives of this study were to confirm results of earlier studies using clinically confirmed cataract cases, investigate possible confounding of the relationship, and examine whether the risk of cataract is modified by stove type or ventilation.

Methods

Human subjects' approvals were obtained from the Committee for the Protection of Human Subjects at the University of California, Berkeley, and from the Nepal Health Research Council.

We conducted a case–control study among women visiting Shree Rana Ambika Shah Eye Hospital, located in Nepal at the border with India. This hospital is a major eye care centre for people living in adjoining districts in India and several districts in the plain areas of Nepal. The study was limited to women because only women do the cooking in this area and our major hypothesis involved smoke from cooking. Cases and controls in this study all resided in Maharajgunj and Gorakhpur districts in India, and Rupandehi, Nawalparasi, and Kapilvastu districts in Nepal. All subjects were recruited and interviewed between July and October 2002.

Recruitment procedures for cases and controls

Cases and controls were all females, aged between 35 and 75 years, visiting the outpatients' department of Shree Rana Ambika Shah Eye Hospital. All subjects were self-referred patients and were visiting this hospital for the first time. As a general procedure, every patient visiting the outpatient department goes first to the eye examination room where their visual acuity is measured and a preliminary eye diagnosis is made. Patients are then sent to more specialized clinics (e.g. refractive error or cataract). At the cataract clinic, patients undergo a confirmatory slit lamp examination after the pupils of their eyes have been dilated.[34–36] Patients at the refractive error clinic are further tested for glasses and cataract is excluded by slit lamp examination. In this study, we recruited cases from the cataract clinic after an ophthalmologist confirmed that they had cataract, and controls from the refractive error clinic after it was confirmed that they did not have a cataract. Recruiting staff were unaware of the main purpose of the project. Similarly, the interviewer was not aware of the specific study hypotheses, but was aware of the subjects' diagnoses at the time of interview.

Once an interview had been conducted with a cataract case, the next eligible patient was recruited as a control from the refractive error clinic. This systematic procedure was used to obtain a control sample frequency matched to cases in 5-year age bands. Patients with a history of diabetes mellitus were excluded from both case and control groups, as were cases with infantile or congenital cataract. We sought to enrol at least 200 cases and 200 controls.

All cases and controls were interviewed face-to-face, shortly after diagnosis and while they were still at the hospital. A verbal consent to participate was obtained from all subjects before the interview. The questionnaire collected data on education level, area of residence (urban or rural), history of use of cooking stoves and fuels, kitchen type and location, ventilation, house type, smoking status of the interviewee and her husband, alcohol consumption, vitamin use, use of mosquito coils and incense, history of severe diarrhoea, present food habits, frequency of milk, meat, and green vegetable consumption, whether taking vitamin supplements, household crowding, hours worked outside, protection from exposure to sunlight, vaccination during childhood, and variables related to socioeconomic status.

Statistical analysis

For the statistical analysis we constructed a trichotomous variable for the combination of stove and fuel type. Stoves that used non-solid fuels—kerosene, liquefied petroleum gas (LPG), biogas, or electricity—were designated as 'clean-fuel stoves' (CFS), and used as the reference category for most analyses. Solid-fuel-burning stoves without flues were designated as 'solid-fuel-unimproved stoves' (SFUS), and solid-fuel-burning stoves, with flues were designated as 'solid-fuel-improved stoves' (SFIS). For some analyses, the CFS and SFIS categories were combined as the reference category.

We combined information on kitchen location and windows in the kitchen to create a composite dichotomous variable for ventilation. 'Fully and partially ventilated kitchens' included open-air kitchens, separate kitchens outside the house, and partitioned kitchens with windows inside the house. This was used as the reference category for ventilation. 'Unventilated kitchens' included partitioned and non-partitioned kitchens without windows inside the house.

The level of education of subjects in the study was low. Therefore, as a surrogate for education level, we used literacy, dichotomized as literate (reference category) and illiterate. Illiterate subjects were those who could not read certain religious texts, had not attended formal schools or adult literacy classes, and could not write a letter. For occupation, to form the reference category, we combined the small proportion of women who worked in offices or businesses (4.4% of controls and 2.4% of cases) with the women who worked only at home. The remaining women worked on farms. For type of lighting at home we combined wick lamps and lanterns, comparing them with use of electricity for lighting (reference category).

We evaluated potential confounders of the relationship between cataract and stove fuel combination by comparing adjusted and unadjusted relative risk estimates for the association between stove-fuel type (using the combined CFS and SFIS as the reference category) and cataract.[37] We considered a variable to be a potential confounder if the difference between the unadjusted and adjusted odds ratios (ORs) was more than 10% of the unadjusted value. Using these covariates and including age (matching variable), we constructed a multivariate unconditional logistic regression model[38] to evaluate the effect of cooking method and ventilation status on the risk of cataract.

Duration of cooking on SFUS was categorized into three 20-year bands to investigate the exposure–response relationship. For this analysis, SFIS and CFS were combined as the reference category.

Results

For the study 206 cataract cases (49% nuclear sclerosis, 25% posterior sub-capsular, 2% cortical, 24% mixed types) and 203 controls without cataract (45% presbyopia, 7% myopia, 10% hypermetropia, 9% astigmatism, 25% mixed types, and 3% with no diagnosed eye disorder) were recruited and interviewed. Except for one case, all potential interviewees agreed to participate in this study. Table 1 shows descriptive characteristics of the cases and controls. Confirming the success of the matching process, distributions of cases and controls were similar in terms of age, and by religion. However, a slightly higher proportion of cases was from India, cases were more likely to live in rural areas ($P < 0.01$) and less likely to be literate ($P < 0.01$). Moreover, cases were more likely to be using SFUS; conversely, controls were more likely to be using CFS ($P < 0.01$). The predominant type of solid fuel was animal dung (78% of SFUS users and 64% of SFIS users), followed by wood (19% of SFUS users and 36% of SFIS users).

The unadjusted exposure ORs for cooking in SFIS and SFUS were 1.98 [95% confidence interval (CI) 0.78–5.04] and 3.39 (95% CI 2.10–5.46), respectively. Similarly, compared with cooking in a fully or partially ventilated kitchen, cooking in an unventilated kitchen was associated with more than a doubling of the risk of cataract (OR 2.38, 95% CI 1.57–3.62).

As the univariate analysis showed statistically significant associations of cataract with literacy, urban/rural residency, occupation, ventilation in the kitchen, source of light, regular intake of vegetables and a glass of milk, work outside, house type, and age at which cooking started, we investigated all these variables as potential confounders of the relationship between stove-fuel type and cataract. Illiteracy, urban/rural residency, lighting type, use of incense, and lack of ventilation were confounders of the relationship, according to our criterion of 10% change from the unadjusted value (Table 2). These were included in our main logistic regression model.

In addition to the identified confounding variables, we included age and work outside in our logistic regression model. Age was included as it was a matching variable, and work outside because exposure to sunlight as it is known to be a major independent risk factor for cataract. Table 3 shows the associated ORs. Both use of SFIS and SFUS were associated with increased risk of cataract, compared with use of CFS.

We investigated whether ventilation in the kitchen modified the risk of cataract associated with type of stove fuel. For this purpose, we combined CFS and SFIS as the reference category and created separate logistic regression models for subjects who cooked in ventilated kitchens and for subjects who cooked in unventilated kitchens. Results are shown in Table 4. They suggest only a slight effect modification by ventilation of the risk associated with use of SFUS.

Table 1 Descriptive analysis of characteristics of cataract cases and controls

Variables	Cases (%)	Controls (%)	Univariate OR (95% CI)
Age[a]			
35–39 years	35 (17.2)	39 (18.9)	
40–44 years	41 (20.2)	39 (18.9)	
45–49 years	72 (35.5)	67 (32.8)	
50–54 years	39 (19.2)	40 (19.4)	
55–59 years	12 (5.9)	18 (8.5)	
>59 years	4 (2.0)	3 (1.5)	
Country			
Nepal	101 (51.0)	113 (55.7)	0.77 (0.51–1.15)
India	105 (49.0)	90 (44.3)	1.00
Area of residence			
Urban	15 (7.3)	42 (20.8)	1.00
Rural	191 (92.7)	160 (79.2)	3.34 (1.73–6.72)
Religion			
Hindu	168 (81.6)	165 (81.7)	1.00
Muslim	38 (18.5)	37 (18.3)	1.01 (0.60–1.72)
Literacy			
Literate	27 (13.1)	54 (26.6)	1.00
Illiterate	179 (86.9)	149 (73.4)	2.40 (1.40–4.17)
House type[b]			
Pucca or semi pucca house	158 (76.7)	171 (84.7)	1.00
Kuccha house	48 (23.3)	31 (15.3)	1.68 (1.00–2.86)
Crowding			
⩽3 people per room	135 (65.5)	157 (77.3)	1.00
>3 people per room	71 (34.5)	46 (22.7)	1.80 (1.13–2.85)
Source of light in the house			
Electricity	89 (45.0)	126 (65.6)	1.00
Wick lamp or lantern	109 (55.0)	66 (34.4)	2.34 (1.52–3.59)
Current fuel and stove use			
Clean fuel stove (CFS)	32 (15.5)	76 (37.4)	1.00
Solid fuel improved stove (SFIS)	10 (4.9)	12 (6.0)	1.98 (0.78–5.04)
Solid fuel unimproved stove (SFUS)	164 (79.6)	115 (56.6)	3.39 (2.10–5.46)
Kitchen location			
Open air kitchen and cooking both outside and inside	27 (13.1)	23 (11.3)	1.00
Separate kitchen room outside the house	41 (19.9)	55 (27.1)	0.64 (0.32–1.26)
Partitioned kitchen inside the house	65 (31.6)	86 (42.4)	0.64 (0.34–1.22)
Non-partitioned kitchen inside the house	73 (35.4)	39 (19.2)	1.59 (0.81–3.14)
Ventilation in the kitchen			
Fully ventilated kitchen	87 (42.2)	129 (63.6)	1.00
Unventilated kitchen	119 (57.8)	74 (36.4)	2.38 (1.57–3.62)
Age started cooking			
⩽13 years	155 (76.4)	136 (67.0)	1.59 (1.01–2.52)
>13 years	48 (23.6)	67 (33.0)	1.00
Vegetable intake			
Yes/regularly	167 (81.5)	183 (90.2)	1.00
No or only sometimes	38 (18.5)	20 (9.8)	2.08 (1.13–3.93)

Table 1 continued

Variables	Cases (%)	Controls (%)	Univariate OR (95% CI)
Meat intake			
⩽3 times per month	154(74.8)	131(64.5)	1.63 (1.06–2.49)
>3 times per month	52(25.2)	72(35.5)	1.00
A glass of milk every day			
Yes	97 (47.1)	120 (59.4)	1.00
No	109 (52.9)	82 (40.6)	1.64 (1.09–2.48)
Taking vitamin supplements			
Yes	9 (4.4)	18 (9.0)	1.00
No	197 (95.6)	184 (91.0)	2.14 (0.89–5.54)
Alcohol consumption			
No	195 (95.6)	189 (95.0)	1.00
Yes	9 (4.4)	10 (5.0)	0.87 (0.31–2.45)
Occupation			
Housewife or services/ business	69 (33.7)	94 (46.5)	1.00
Farming	136 (66.3)	108 (53.5)	1.72 (1.13–2.61)
Daily work outside			
<1 h	66 (32.4)	85 (41.9)	1.00
⩾1 h	138 (67.6)	118 (58.1)	1.51 (1.00–2.31)
Protection from exposure to sunlight (veil/burka use)			
Yes	144 (70.2)	137 (67.5)	0.88 (0.57–1.37)
No	61 (29.8)	66 (32.5)	1.00
Smoking status			
Never smoker	157 (76.2)	160 (78.8)	1.00
Smoking present or past smoker	49 (23.8)	43 (21.2)	1.16 (0.71–1.90)
Husband a smoker?			
No	62 (30.2)	66 (32.5)	1.00
Yes	143 (69.8)	137 (67.5)	1.11 (0.72–1.73)
Burn mosquito coils indoors			
No	186 (91.2)	180 (89.1)	1.00
Yes	18 (8.8)	22 (10.9)	0.79 (0.39–1.60)
Number of incense sticks burned each day			
⩽2 sticks	154(74.8)	123(60.6)	1.00
>2 sticks	52(25.2)	80(39.4)	0.52 (0.34–0.79)
Vaccination in childhood			
Yes	141 (77.5)	153 (82.3)	1.00
No	41 (22.5)	33 (17.7)	1.35 (0.78–2.33)
Severe diarrhoea in the last 5 years			
Yes/sometimes	80 (39.0)	70 (34.0)	1.22 (0.80–1.86)
No	125 (61.0)	133 (66.0)	1.00
Land ownership			
Yes	184 (89.3)	171 (84.2)	1.00
No	22 (10.7)	32 (15.8)	0.64 (0.34–1.19)

[a] ORs ratios not appropriate, as age was a matching variable.

[b] Pucca, house made with brick and cement; semi pucca, house made with brick and mud; kuccha, house made with bamboo and mud (with thatched roof).

Table 2 Investigation of the change in the Mantel–Haenszel (M–H) OR for cataract after adding potential confounding variables to the model (SFUS compared with improved solid-fuel stoves and CFS combined)

Potential confounding variable	M–H OR (95% CI)	% Difference
None	2.99 (1.93–4.62)	0
Literacy (reference: literate)	2.63 (1.67–4.12)	−12
Area of residence (reference: urban)	2.49 (1.56–3.98)	−17
Occupation (reference: housewife or services/business)	2.78 (1.74–4.44)	−7
Kitchen ventilation (reference: ventilated)	2.50 (1.59–3.93)	−16
Age started cooking (reference: >13 years)	2.90 (1.86–4.51)	−3
Regular vegetable intake (reference: yes)	2.81 (1.81–4.38)	−6
Daily glass of milk (reference: yes)	2.81 (1.81–4.37)	−6
Meat intake per month (reference: >3 times)	2.83 (1.81–4.42)	−5
Work outside (reference <1 h per day)	2.88 (1.81–4.59)	−4
House type (reference: pucca or semi-pucca)	2.88 (1.84–4.51)	−4
Crowding (reference: ⩽3 people per room)	2.79 (1.79–4.34)	−7
Source of light in house (reference: electricity)	2.45 (1.45–4.13)	−18
Incense burned (reference: ⩽2 sticks per day)	2.68 (1.70–4.20)	−10

Table 3 Main logistic regression model for cataract in women from India and Nepal

Variable	OR[b]	95% CI	*P*-value
Clean fuel stove	1.00	–	–
Solid fuel improved (vented) stove	1.23	0.44–3.42	0.69
Solid fuel unimproved (unvented) stove	1.90	1.00–3.61	0.05
Kitchen ventilation[a]	1.96	1.25–3.07	0.003
Work outside[a]	0.60	0.36–1.02	0.06
Literacy[a]	1.48	0.80–2.73	0.21
Area of residence[a]	2.28	1.09–4.76	0.03
Source of light in house[a]	1.37	0.81–2.32	0.24
Incense burned[a]	0.85	0.53–1.39	0.52

[a] See Table 2 for categories.

[b] ORs for age are not included, as age was a matching variable.

Exposure–response

We investigated whether the risk of cataract varied according to duration of cooking with SFUS. The durations of cooking on SFUS by cases and controls were categorized into 20-year bands. There was some evidence of an exposure-related trend in the risk of cataract with increasing duration of cooking with SFUS (Table 5). However, as the number of subjects in our reference group (no use of unimproved stoves) was small, the results are imprecise.

Table 4 Effects of ventilation on risk associated with SFUS use

Current kitchen ventilation	OR[a]	95% CI	*P*-value
All subjects ($n = 387$)	1.96	1.25–3.07	0.003
Ventilated ($n = 206$)	1.81	0.89–3.68	0.10
Unventilated ($n = 181$)	1.91	0.70–5.20	0.21

[a] Adjusted for age, literacy, work outside, urban/rural residency, incense use, and source of light in the house (see Table 2 for more detail on categories).

Table 5 Exposure response relationship based on duration of cooking with SFUS

Exposure to SFUS	Cases (%)	Controls (%)	OR[a,b]	95%CI
0 (Never)	6 (2.9)	18 (8.9)	1.00	–
1–19 years	50 (24.4)	60 (29.7)	1.68	0.59–4.83
20–39 years	122 (59.5)	110 (54.5)	1.38	0.48–3.97
>40 years	27 (13.2)	14 (6.9)	2.00	0.55–7.27

[a] Adjusted for age, literacy, work outside, ventilation in the kitchen, urban/rural residency, incense use, and source of light in the house (see Table 2 for more detail on categories).

[b] Test for trend, $P = 0.66$.

Discussion

The results of this study confirm findings from previous studies that risk of cataract is increased by indoor exposure to smoke from solid-cooking-fuel combustion.[26,33] However, before concluding that the association is causal, it is important to consider alternative explanations, particularly the possibility that the study results might be a result of selection bias, information bias, or confounding in the study design or analysis. As with all case–control studies, selection bias in recruitment of controls is an important concern. In this study, we used a systematic procedure for recruitment of controls from the refractive error clinic and there were no refusals to participate by selected potential controls. Only one selected case refused to participate. The study hospital is the only eye hospital in the surrounding area (~5200 sq km in Nepal and 6000 sq km in India).[39,40] Therefore, selection bias in this study appears unlikely.

Information bias may take the form of either outcome or exposure misclassification. Since our cataract cases were slit-lamp confirmed, and controls were similarly confirmed as not having cataract, disease misclassification is highly unlikely. All exposure data were obtained by questionnaire. Case–control studies are often considered potentially susceptible to recall bias, in that cases may be more likely than the controls to remember past exposures. However, in this study, since we asked questions about common exposures, which both cases and controls come across on a day-to-day basis, we expect that any such differential recall bias would be minimal. In particular, all of the participants know very well the types of stoves and fuel they have used, and there is no prevailing belief that indoor smoke exposure from unimproved stoves is harmful to health. The main analysis is based on the current use of stove fuel. The general tendency among study subjects was to change to cleaner-burning stove-fuel combinations. Therefore, some of our comparison group, currently using clean-burning stove-fuel combinations, will have previously used unflued solid-fuel stoves. This would have biased the ORs towards the null.

There is likely to be some degree of non-differential exposure misclassification, which would have affected some variables more than others. Ventilation status, for example, may be more substantively misclassified than, say, use of mosquito coils, because there is more variability in ventilation arrangements and it is difficult to encapsulate these in a series of simple questions. We would expect such misclassification generally to bias relative risk estimates towards the null.

The third main area of potential bias is confounding. In the first publication to report an association between use of solid cooking fuels and cataract, it was suggested that the explanation could be confounding by other socioeconomic factors.[26] The present study collected a comprehensive range of data on potential confounding factors, particularly those associated with socioeconomic status, and investigated their potential to confound the association with use of SFUS. Although confounding was present, adjustment with these variables did not eliminate the key associations. Although there may be some residual confounding, and we cannot rule out the possibility of an unknown confounding factor causing the associations found, the comprehensiveness of our investigation of potential confounding makes this seem unlikely.

There are several other issues that may be considered in inferring causality.[41] These include the possibility that the results might be caused by chance, consistency with the findings of other studies, and biological plausibility. We cannot rule out the possibility that chance may have played a role in some of our findings, as our sample size was not sufficiently large for this to be ruled out. However, the consistency of our results with those of other studies makes chance a less likely explanation. There have been three other studies that have suggested an association between exposure to indoor cooking smoke and cataract or blindness.[26,32,33] We are not aware of any studies that have investigated the relationship between cataract and indoor smoke exposure that have found no evidence of an association. Our findings, therefore, are consistent with and strengthen the findings of earlier studies indicating that cooking with solid fuel in unimproved stoves increases the risk of cataract. We also found lack of ventilation in the kitchen to be an independent risk factor for cataract. Presence of ventilation did not seem to substantially reduce the relative risk for cooking with a SFUS. This could be due to cooks remaining very close to their stoves and receiving high smoke exposure, irrespective of ventilation.

A causal relationship between exposure to indoor smoke and cataract is biologically plausible. There is evidence that smoke can induce oxidative stress and deplete plasma ascorbate, carotenoids, and glutathione, which provide antioxidant protection against cataract formation.[42–44] Tobacco smoke and biofuel smoke have many similarities.[42,45] Several studies have indicated that tobacco smoking and fuel smoke condensate enhance the formation of super-oxide radicals, which decrease the formation of antioxidants and increase the risk of cataract.[43,46–49] Studies have shown a possible association of cataract with exposure to naphthalene[50–52] and formaldehyde. Biofuel combustion emits naphthalene[53–56] and formaldehyde[45,57,58] in considerable amounts. However, assuming that the association found in our study reflects a true causal relationship, it is unclear which route of exposure, inhalation or direct eye contact, leads to the pathogenic process of cataract formation.

In conclusion, our study confirms that use of solid fuels in unimproved stoves and accompanying lack of kitchen ventilation are associated with an increased risk of cataract. Bias, including potential confounding, seems unlikely to explain these associations, which are biologically plausible and consistent with the results of other epidemiological studies. The most effective remedial measure would be to replace unflued stoves with flued stoves, which vent cooking smoke directly to the exterior of the house. Ideally, stoves with cleaner-burning fuels, such as gas (biogas, LPG) or kerosene, would be used. However, economic realities may prevent this from becoming widespread. Second, by ensuring that kitchens have some form of ventilation particularly a window, there would be some degree of risk reduction, particularly if unflued stoves are retained. However, our study shows that simply increasing ventilation in the absence of improved stove type would not reduce the relative risk associated with unflued stoves. Worldwide, millions of people, particularly women, are exposed to high levels of indoor smoke from cooking with solid fuels on unvented stoves. The public health benefits of widespread stove improvement, particularly addition of flues, could be immense.

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KEY MESSAGES

- This study presents evidence that cooking indoors with unvented solid-fuel stoves is associated with cataract formation in women doing the cooking. The association does not appear to be caused by confounding or other bias.
- The ideal solution would be to replace the solid-fuel stoves with stoves that use liquid fuel or gas. However, using a vented solid-fuel stove may be a more economic solution and provide good protection.
- Ventilation in the kitchen is useful, but ventilation alone does not provide adequate protection against the effects of unvented solid-fuel stoves.

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