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Biomass Stoves and Lens Opacity and Cataract in Nepalese Women

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Abstract

Purpose—Cataract is the most prevalent cause of blindness in Nepal. Several epidemiologic studies have associated cataracts with use of biomass cookstoves. These studies, however, have had limitations, including potential control selection bias and limited adjustment for possible confounding. This study, in Pokhara city, in an area of Nepal where biomass cookstoves are widely used without direct venting of the smoke to the outdoors, focuses on pre-clinical measures of opacity, while avoiding selection bias and taking into account comprehensive data on potential confounding factors

Methods—Using a cross-sectional study design, severity of lenticular damage, judged on the LOCS III scales, was investigated in females (n=143), aged 20-65 years, without previously diagnosed cataract. Linear and logistic regression analyses were used to examine the relationships with stove type and length of use. Clinically significant cataract, used in the logistic regression models, was defined as a LOCS III score > 2.

Results—Using gas cookstoves as the reference group, logistic regression analysis for nuclear cataract showed the evidence of relationships with stove type: for biomass stoves, the odds ratio (OR) was 2.58 (95% confidence interval [CI]: 1.22-5.46) and, for kerosene stoves, the OR was 5.18 (95% CI: 0.88-30.38). Similar results were found for nuclear color (LOCS III score > 2), but no association was found with cortical cataracts. Supporting a relationship between biomass stoves and nuclear cataract was a trend with years of exposure to biomass cookstoves (p=0.01). Linear regression analyses did not show clear evidence of an association between lenticular damage and stove types. Biomass fuel used for heating was not associated with any form of opacity.

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APPENDIX

An appendix available online at [LWW insert link].

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Conclusions—This study provides support for associations of biomass and kerosene cookstoves with nuclear opacity and change in nuclear color. The novel associations with kerosene cookstove use deserve further investigation.

Keywords

cookstove; heating stove; cross-sectional study; indoor air pollution; kerosene; LOCS III scale

Cataract, from opacification of the crystalline lens of the eye, accounts for more than 50% of reversible blindness worldwide.¹ Globally, the prevalence of cataract is higher in females than in males, and in developing countries cataracts occur at younger ages.²⁻⁴ Nuclear opacity is the most prevalent cataract type in South Asia.^{5, 6} In Nepal, despite networks of eye hospitals throughout the country, cataract-related blindness is still prevalent and only slowly decreasing. For example, in 1981, the Nepal Blindness Survey documented a 3.8% prevalence of bilateral blindness (visual acuity <3/60), mainly due to cataract, in people >45 years.⁷ In 1998, the corresponding prevalence was 3.0%.⁸

Epidemiologic studies have indicated that environmental and genetic factors play an etiologic role in cataract formation.^{9, 10} More than two-fifths of the world's population uses biomass (wood, crop residues and cow dung) as cooking fuel and sometimes space heating. Several epidemiologic studies have associated use of biomass-burning stoves with cataract.¹¹⁻¹⁷ This is plausible, since tobacco smoking has been implicated as a risk factor for cataract¹⁸⁻²³ and tobacco smoke and biomass fuel smoke have some common constituents.^{24, 25} The studies of biomass, however, have had limitations, including possible selection bias in controls. Until now, the focus of epidemiologic studies investigating the use of biomass cookstoves has been the clinical diagnosis of cataract—usually by slit-lamp examination. To our knowledge, however, no study has yet examined associations with the severity of lens changes or pre-clinical cataract. The main aim of this study was to investigate whether cataract at the pre-clinical stage is associated with the use of biomass fuel for cooking and heating in households—based on slit-lamp examination, lens photography and LOCS III grading. Our study design avoids selection bias and allows testing for an exposure-response relationship, based on reported histories of stove use.

METHODS

Human subjects' approvals were obtained from the institutional review boards at the University of California, Berkeley, and the Nepal Health Research Council.

We conducted a cross-sectional study, from July to November 2006, among women, 20-65 years of age, visiting the Outpatient Department (OPD) at Manipal Teaching Hospital, Manipal College of Medical Sciences, Pokhara, Nepal. The study was limited to women, because in Nepal women do most of the cooking. The first five patients present at the OPD between 9:00 and 10:00 each morning were invited to participate. Excluded were women with congenital cataract, women having had previous diagnosis of cataract (since they will usually have had lens surgery), women with macular degeneration (which may have changed their cooking behavior), or women who had had penetrating eye trauma. Pregnant women were excluded for safety reasons, as we dilated pupils for ocular photography.

Women undergoing chemotherapy or with diabetes were also excluded, as these are risk factors for cataract.^{4, 26-28}

Ocular Examination

After oral consent, participants' visual acuities were measured at 3 meters with an illuminated Bailey-Lovie visual acuity chart.²⁹ Visual acuity was measured with habitual correction, with pinhole correction and with best corrected visual acuity. Each eye was measured separately, followed by measurement of intra-ocular pressure and examination of the adnexa and crystalline lens. We used the following criteria to categorize refractive error: (1) Emmetropia: spherical equivalent between -0.50 and $+0.50$ diopter spheres (DS); (2) Hypermetropia: spherical equivalent > 0.50 DS; (3) Myopia: spherical equivalent < -0.50 DS; and (4) Astigmatism: cylindrical error more than 0.50 diopter cylinder (DC) in any axis.

Participants' pupils were then dilated to 7 mm or more with a mixture of 1% Tropicamide and 10% phenylephrine. The crystalline lenses were then re-examined with a slit-lamp, first with diffuse illumination, then with a slit beam, and finally with retro-illumination. The slit lamp had an inbuilt digital camera (Topcon Model SL-D2) and lens photographs were taken when the pupil diameter reached >7 mm.

Lens Photography and Cataract Grading

Cross-sectional slit-lamp photographs were used to document nuclear opalescence (opacity). The vertical beam height was extended to the maximum and the breadth fixed at the minimum. Retro-illumination photographs were obtained to document cortical and posterior sub-capsular cataract severity. The slit beam was fixed at 5 mm high and 1-2 mm wide. Each participant had a total of six lenticular photographs, consisting of one cross-sectional, and two retro-illuminated photographs per eye. All participants had photographs taken.

The digital photographs were sent to the School of Optometry at the University of California, Berkeley, where two experienced graders (IB and RD) scored each photograph by comparison with the LOCS III reference photographs.³⁰ Compared with the simple categorization of cataract as present or absent, the LOCS III system can be used to quantify lenticular changes on four scales (nuclear opacity, nuclear color, and cortical and posterior sub-capsular cataract), with fine increments. For both nuclear opacity and nuclear color, there are six photographs as exemplars of severity grades 1 through 6. Graders assigned decimalized grades, from 0.0 to 6.0 in increments of 0.1. For both the cortical and posterior sub-capsular opacities, there are five photographs as exemplars of severity grades 1 through 5. Possible scores are 0.0 to 5.0, in increments of 0.1.

Consistency of the corresponding scores between the two graders was evaluated graphically using Bland-Altman plots.³¹ This method plots differences between two scores against the average of the two scores. In the event that there were marked differences between graders that could not be readily eliminated by regrading, a consensus approach was used. In this process, batches of 10 photographs were presented simultaneously to the two graders who independently assigned a severity grade. After the independent gradings, the graders revealed their assigned scores to each other, discussed any differences, and came to an agreement on a consensus grade.

For the purposes of the logistic regression analyses, participants were characterized as having evidence of clinically significant cataract if they had a consensus score for nuclear opacity or, for the other color/cataract types, an average score between the graders, of 2.0 or more, in either eye. This criterion has been used in other studies.^{32, 33}

Questionnaire

Questions were asked about each participant's main present and previous cooking stoves: gas, kerosene and biomass. Participants were asked about changes in the fuel type they used since they started actively helping or cooking in the kitchen, before or after marriage, and their duration of use of each stove type.

Questions also covered kitchen location and presence of kitchen windows, as well as presence in the home of other sources of indoor emissions, such as heating fuel, household lighting and burning mosquito coils or incense. Detailed histories of tobacco smoking and alcohol consumption, exposure to environmental tobacco smoke, sunlight exposure (time worked outside each day and number of years of work), and protection from sunlight were collected.

Other questions focused on socio-economic status (annual family income, education, area of residency) and dietary practices.

Statistical Analysis

Information on kitchen location and presence of opening windows in the kitchen was combined to create a composite dichotomous ventilation variable.¹⁴ Kitchens were categorized as “fully/partially ventilated” when they were open-air kitchens or kitchens indoor or in a separate structure with an opening window. Kitchens were categorized as “un-ventilated” when they were separate kitchens outside without windows or partitioned kitchens inside without windows or non-partitioned kitchens inside the house.

Pack-years of smoking was calculated as the average number of cigarettes or *bidis* (South Asian cigarettes with tobacco wrapped in a tendu leaf) smoked per day multiplied by the duration in years of smoking, divided by 20, assuming that a pack contains 20 tobacco products.³⁴

The initial analysis was descriptive and examined the mean scores for participants categorized according to basic demographic variables and a number of known risk factors for cataract, including UV exposure³⁵⁻⁴⁴, tobacco smoking¹⁸⁻²³ and lower socio-economic status^{11, 45-48}, after averaging scores across eyes and across graders. Average consensus scores for the two eyes were used for nuclear opacity. ANOVA tests were used to examine differences between the categories. Also examined descriptively, according to levels of the same variables, were the proportions of individuals designated as having cataract. Chi-square tests were used to examine differences between categories.

For each participant and type of opacity/cataract, there were two (consensus) scores for nuclear opacity, and four scores (2 graders and 2 eyes) for nuclear color, and cortical and posterior-sub capsular cataract types. All scores were used in the analysis. We selected

variables for the final regression models in the following way. First, we selected the variables that are directly related to exposure to participants (heating fuel and ventilation in the kitchen). Then, we identified remaining potential confounders of the association with stove type by examining (i) the association between stove type and potential confounders in the group without cataract (LOCS III score <2) and (ii) the association between stove type and potential confounders in the group using only reference stove type (LPG). Any variables which had a statistical association of $p < 0.2$ in chi-square test in both (i) and (ii) were considered for inclusion as additional covariates in the model. However, household lighting type was not included, as virtually everyone used electricity or solar lamps: only two participants reported they used kerosene wick lamps.

Since opacity scores obtained from the two eyes of a single individual are likely to be positively correlated, their inclusion in the same statistical analysis violates the assumption of statistical independence, and may result in overly reduced variances.⁵² This was addressed by using a robust-variance option in the multivariate risk models.⁵³ This option adjusts for within-cluster correlation and gives robust standard errors with unbiased 95% confidence intervals for the mean scores.⁵⁴

Linear and logistic multivariate regression models were used to estimate associations of exposures with opacity. First, opacity/color/cataract scores on continuous scales were analyzed by multivariate linear regression with the robust option. Secondly, the scores were dichotomized into those with and without evidence of clinically significant cataract, applying a cut-point score of 2.0. Odds ratios for cataract were then calculated for nuclear cataract, nuclear color and cortical cataract with logistic regression, also using the robust-variance option. Since very few participants had posterior sub-capsular cataract, we did not calculate the odds ratios for this cataract type.

Exposure-response patterns of clinically significant cataract by duration of use of biomass cookstoves were examined with logistic regression analysis. We used 20 year use duration categories, similar to those we used in a previous study.¹⁴

RESULTS

A total of 145 women aged 20 to 65 years were invited to participate. Of these, one woman who was pregnant and one with congenital cataracts were excluded. Full data were available for 143 participants. The majority of participants (70%) were emmetropic, with 15% having hypermetropia and 14% myopia. The prevalence of astigmatism was 13%. The mean and the standard deviation of intra-ocular pressure were 14.0 and 2.9 mm Hg, respectively.

Visual inspection of Bland-Altman plots for nuclear opacity scores of the two graders showed a linear trend, with negative differences for low mean scores and positive differences for higher values, indicating a systematic difference between the two scorers. Compared to the other grader, one grader tended to give slightly lower scores at the low end of the range and higher scores at the high end. Consequently, the nuclear opacity photographs were regraded after some retraining of the scorers. The rescoring reduced, but did not totally remove, the trend evident in the Bland-Altman plots. Therefore, for the

analysis of nuclear opacity, we used consensus scores. For nuclear color and cortical and posterior sub-capsular cataract types, there was no evidence from the Bland-Altman plots of a systematic difference between scorers and 93-95% of scores fell within 2 SD of the mean opacity scores. For the analyses of these types, we used average scores, across both eyes, of the two graders.

Table 1 presents demographic and exposure data, and mean scores for the three types of opacification/cataract and change in nuclear color. The mean age of participants was 45 years (SD: 12 years). Ninety-five percent were Hindu, 50% were illiterate (could not read or write Nepali), and 86% were urban residents. Forty percent currently used biomass stoves without chimneys or hoods and none reported that they had ever used biomass stoves with chimneys or hoods. Fifty-seven percent reported using a gas cookstove (LPG or biogas) and only 5 participants (3.5%) used kerosene cookstoves. Ninety-nine percent of participants had electricity supply to their houses and 79% reported well-ventilated kitchens. Forty-five (32%) reported they had smoked tobacco, but of those, only 17 (38%) were current smokers. Each of the opacity/cataract types and nuclear color was statistically associated with several of the demographic and exposure variables.

The mean score for nuclear opacity was 2.11 (SD: 0.73); for nuclear color, 1.70 (SD: 0.76); cortical cataract, 0.95 (SD: 0.85); and posterior sub-capsular cataract, 0.22 (SD: 0.46).

Table 2 presents the distribution of nuclear cataract (LOCS III score > 2.0), according to the set of demographic variables used in Table 1. It shows the prevalence of cataract increasing with age-group, a higher prevalence in ever-smokers and with greater pack-years of smoking, and a higher prevalence in women who are illiterate. Although there were only 5 women who used kerosene for cooking, 4 of them had cataract (80%), compared with 55% in all the other participants.

Table 3 presents the results of multivariate logistic regression analyses, separately by color/cataract type. Corresponding linear regression analyses by opacity/color/cataract type are in the Appendix/table A1, available online at [\[LWW insert link\]](#).

Using gas as the reference category, nuclear cataract showed the strongest evidence of relationships with stove types: for biomass stoves, the odds ratio (OR) was 2.58 (95% confidence interval [CI]: 1.22-5.46; $p = 0.01$) and for kerosene stoves, the OR was 5.18 (95% CI: 0.88-30.38; $p = 0.07$). Similar, if slightly weaker, relationships were observed for nuclear color (LOCS III > 2): for biomass stoves, the OR was 1.98 (95% CI: 0.82-4.74; $p = 0.13$) and for kerosene stoves, 5.48 (95% CI: 1.23-24.37; $p = 0.03$). Cortical cataract showed no evidence of association with either biomass or kerosene stoves.

The linear regression analysis examined associations of variables in Table 1 with scores on a continuous scale. The logistic regression analysis examined associations between variables in Table 1 and scores classified as clinically significant cataract (LOCS III score > 2.0). The reference category for stoves was gas stoves.

The linear regression analysis produced positive coefficients for both biomass and kerosene stoves in relation to nuclear opacity and nuclear color scores, but confidence intervals

always included the null value, zero (Table S1). Negative coefficients were obtained for cortical opacity scores for both biomass and kerosene stoves. For posterior subcapsular opacity scores, a negative coefficient was found for biomass stoves but a positive coefficient for kerosene stoves. Both confidence intervals included the null. For each opacity type, the coefficient for kerosene stoves was larger than that for biomass stoves (in the case of cortical opacity, in a negative direction).

As would be expected, increasing age (as a categorical variable) was positively associated with opacity categories in all models.

The linear regression models explained 35% of variance for nuclear opacity, 55% for nuclear color, 22% for cortical cataract, and 16% for posterior subcapsular cataract.

Use of biomass fuel used for heating showed no evidence of an association with any of the forms of opacity in linear regression analyses or cataract in the logistic regression analyses. Table 4 presents exposure-response relationships from logistic regression for each cataract type (LOCS III > 2.0), based on 20-year bands of biomass cookstove use. A corresponding analysis was not carried out for kerosene stoves because of the small number of participants who had used them. For increasing duration of use of biomass fuel there was a monotonic increasing trend in the ORs for nuclear opacity ($p = 0.01$) and some evidence for nuclear color ($p = 0.07$). For the cortical opacity, the longest exposure category had the highest odds ratios, but overall trends were less apparent ($p = 0.33$).

DISCUSSION

The results of this study provide evidence that exposure to air pollutants from cooking with biomass or kerosene may increase the risk of nuclear cataract and change in nuclear color (LOCS III > 2.0) in this population of Nepalese women. We found little evidence of associations between biomass for cooking or heating, or kerosene use for cooking, with changes in cortical cataract.

Previously, seven epidemiologic studies have consistently suggested an association between biomass cookstove use and cataract or blindness.¹¹⁻¹⁷ We are not aware of any such studies that found no evidence of an association. Potentially, however, selection bias, information bias, or confounding could have influenced results of these studies. Selection bias in recruitment of participants was of concern in our previous study of cataract and cookstove use in Nepal. In that study, controls were selected from patients with refractive error.¹⁴ There is evidence of an association between refractive error and higher education, a surrogate for socio-economic status, which is likely to be a correlate of stove type.⁵⁵⁻⁵⁷ Our controls appeared to be of higher socio-economic status than the experimental population. Thus, it was possible that controls represented a different population, with different exposure patterns, including lower exposure to biomass fuel smoke, than the population represented by the cases. In the present study, we did not select controls and all participants were drawn from the same patient population. The possibility of selection bias from recruiting only cooperative participants was avoided by a systematic recruitment process for

all participants. There were no refusals to participate. Therefore, we believe that potential for selection bias is low in this study.

Information bias may take the form of outcome or exposure misclassification. In this study, LOCS III scores were confirmed by two scorers independently evaluating the photographs according to an agreed protocol. Since we found some observer inconsistency for scoring nuclear opacity, we addressed this problem by obtaining consensus scores.

Grading the severity of lenticular changes from a single slit-lamp photograph is a complex task because identical severity scores may be given to cataractous changes quite different in their appearance. For the slit lamp photographs used to evaluate nuclear opacity there was always a gradation of the quality of focus along the antero-posterior axis and this could have influenced the severity scores. When there were large discrepancies between the two graders' scores, they were usually due to differences in the balance of the importance given to broadly distributed, diffuse opacification versus well-defined regions of opacity. The consensus scoring procedure minimized the effect of these discrepancies. Scheimpflug camera systems can bring the whole cross-section of the lens into focus at the same time and this would eliminate the variation in the quality of focus across the photograph, making scoring easier. While Scheimpflug systems are expensive, they might be considered for use in future studies.⁵⁸

One method of evaluating the validity of opacity scoring is to examine results for well-established strong predictors of opacity or cataract. Two of these for which we collected data are age and cigarette smoking. In all our statistical models age was the most consistent predictor variable, and in the logistic regression model for nuclear cataract, known to be caused by smoking, the highest smoking category (>9 pack-years) had the highest odds ratio (adjusted OR = 2.55, 95% CI:0.81,8.00). These results provide confidence in the scoring procedures that were used. Any outcome misclassification is likely to be non-differential by stove type and, therefore, to bias results towards the null.

Exposure data were obtained by questionnaire and the cataract graders were not aware of participants' exposure status. However, theoretically at least, some potential for information bias may have arisen from the manner in which the participants' photographs were labeled. For the original gradings the photographs were labeled with study ID and age. The age information potentially could have influenced the graders to give higher LOCS III scores for older participants and, ideally, participants' ages should have been masked. For the regrading of nuclear opacity the age information was deleted. For all the photograph sets, the photographs for the right eye were immediately followed by the photographs for the left eye from the same person. Knowing the LOCS III scores assigned to the right eye, might have influenced the scores assigned to the left eye. Any such bias will, to at least some extent, have been corrected in the multivariate risk models, by use of the robust option.

Participants in this study were not aware of their own lens opacity status, so their responses could not have been influenced by this knowledge. Diabetes is an important risk factor for cataract. We asked participants about previously diagnosed diabetes, but did not conduct objective clinical tests to rule out this condition. Although no participants reported this

diagnosis, the possibility remains that some may have had undiagnosed diabetes. Since any such mis-classification is likely to be unrelated to fuel use status, this should have no effect on results or, at worst, tend to bias results towards the null.

There may be some degree of non-differential exposure misclassification, which is likely to affect some variables more than others. However, the questions asked were about common exposures, encountered by participants on a daily basis and which would generally change infrequently. In particular, there is no reason to believe that the participants would have mis-identified the types of cookstoves or fuels they used. In that regard, we verified the high level of accuracy of reporting of two key exposure variables--fuel type and ventilation in the kitchen--in the homes of 28 participants in another study conducted at the same time and in the same area, and for which the exposure questions were the same.⁵⁹ Thus, exposure misclassification is likely to be minimal, at least for fuel type. One possible limitation, however, is that we asked about only the main cooking fuel used. This might have led to some misclassification of exposure status, as people may also use a secondary fuel. This would tend to bias results towards the null. Similarly, we did not collect information on whether participants, when they were children, accompanied their mothers while they cooked. Not taking this into account would have caused us to underestimate exposures. Since this mis-classification is likely to have been non-differential by present stove/fuel type, it would also tend to bias estimates towards the null.

The third main area of potential bias is confounding. In one large case-control study, which suggested that indoor cooking fuel smoke was associated with cataract, authors reported that it was likely that the association found between biomass fuel use and cataract formation was confounded by factors related to socio-economic status.¹¹ The present study collected a comprehensive range of data on potential confounding factors, particularly those associated with socio-economic status. In the bivariate analysis (Table 1), the mean opacity scores did not vary by family income, generally regarded as a good indicator of socio-economic status. The mean opacity score, however, varied by level of education and land ownership. We adjusted for level of education in all models, but this did not eliminate the associations found with nuclear opacity and nuclear color. We cannot rule out, however, the possibility of an unknown confounding factor causing the associations found.

Except for the study of Mohan et al ¹¹, other studies on indoor air pollution and cataracts did not examine cataracts by type. In that study, use of biomass fuels was found to be associated with increased risk of nuclear and cortical cataracts (as well as mixed cataracts—not directly evaluated in our study), but not with posterior sub-capsular cataract. This is, to some extent, consistent with our finding that the strongest evidence was for an association with nuclear opacity.

Providing support for a relationship between use of biomass cookstoves and nuclear cataract, we found an exposure-response trend (p for trend 0.01) for increasing years of use (Table 4).

A causal relationship between exposure to smoke from biomass fuel combustion and cataract is biologically plausible. There is evidence that smoke from tobacco and biomass

fuel combustion can induce oxidative stress by depleting antioxidants, such as plasma ascorbate, carotenoids, superoxide dismutase and glutathione.^{24, 60-62} These antioxidants protect against cataract formation.¹¹ In addition, studies have indicated that tobacco and biomass fuel smoke condensate enhance the formation of super-oxide radicals, which decrease antioxidants and cause lens discoloration and cataract.^{24, 63-66} Both biomass and kerosene fuel combustions emit naphthalene⁶⁷⁻⁷⁰, which has been shown to cause cataract in laboratory animal studies.⁷¹⁻⁷³ In the previously mentioned indoor air pollution study conducted in the 28 households in the study area, naphthalene concentrations were found to be higher from biomass and kerosene stoves than from gas stoves (results not shown here).⁷⁴ It is unclear whether direct entry of the combustion products into the eyes or inhalation of smoke, and/or heat from the stove leads to the pathogenic process of cataract formation. Some studies have indicated that exposure to high ambient temperatures damages lenses.⁷⁵⁻⁷⁷

In conclusion, this study provides support for previous evidence that use of biomass cookstoves is associated with an increased risk of cataract, specifically nuclear opacification. It also provides a suggestion that kerosene use for cooking may be a risk factor for nuclear cataract and nuclear color. Although we had only 5 participants who reported using kerosene stoves (mean duration of use 7.5 years), 4 of them (80%) had nuclear cataract, compared to 55% of the other participants (Table 2). Kerosene fuel is widely used for cooking in low and middle income countries, but, to the best of our knowledge, has not previously been investigated as a cataract risk factor. This study provides justification for such an investigation to take place as kerosene is also widely used for lighting in the developing world. Bias, including potential confounding, does not provide an obvious explanation for the association with nuclear cataract, which is biologically plausible. Chance, however, cannot be excluded and a larger population-based study, possibly with similar design, is needed to confirm these findings. Irrespective of the evidence for an association between biomass cookstoves and nuclear opacity, traditional biomass cookstoves produce substantial indoor and outdoor air pollution, including naphthalene and fine particulate matter. Therefore, replacement with cleaner alternatives, such as LPG, electricity, or advanced combustion biomass cookstoves, is justified. If the association with nuclear lens opacity is confirmed in larger studies, consideration might also be given to targeting cooks in biomass-using (and possibly kerosene-using) households for early screening of lens opacity as part of cataract prevention programs.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Distribution of LOCS III scores (averaged across both eyes and both graders) for study exposures and covariates in all participants (n = 143), Pokhara, Nepal.

	N (%)	Mean score (standard deviation)			
		Nuclear Opacity ^a	Nuclear Color	Cortical Cataract	Posterior Sub-capsular Cataract
Age in years					
20-29	11 (7.69)	1.47 (0.42) *	0.58 (0.38) *	0.48 (0.47) *	0.03 (0.06) *
30 - 39	35 (24.48)	1.70 (0.45)	1.18 (0.46)	0.65 (0.56)	0.15 (0.30)
40 - 49	44 (30.77)	1.99 (0.52)	1.64 (0.48)	0.76 (0.68)	0.15 (0.27)
50 +	53 (37.06)	2.61 (0.77)	2.34 (0.60)	1.39 (1.00)	0.36 (0.69)
Religion					
Hindu	136 (95.10)	2.11 (0.73)	1.71 (0.76)	0.94 (0.86)	0.22 (0.46)
Buddhist	6 (4.20)	1.93 (0.78)	1.43 (0.85)	0.88 (0.71)	0.15 (0.22)
Christian	1 (0.70)	3.05 (0.35)	1.99 (0.14)	1.58 (0.39)	0.72 (0.77)
Residence locality					
Rural	20 (13.99)	1.90 (0.74) *	1.46 (0.67) *	0.92 (0.85)	0.12 (0.18) *
Urban and Peri-urban	123 (86.01)	2.14 (0.69)	1.74 (0.77)	1.09 (0.86)	0.23 (0.49)
Tobacco smoking					
Never	98 (68.53)	1.99 (0.71) *	1.55 (0.71) *	0.81 (0.75) *	0.18 (0.35) *
Ever	45 (31.47)	2.36 (0.71)	2.02 (0.77)	1.22 (0.97)	0.30 (0.61)
Pack years of smoking					
0	96 (67.13)	1.98 (0.71) *	1.55 (0.71) *	0.81 (0.75) *	0.18 (0.35) *
>0 & ≤ 9 pack-years	24 (16.78)	2.27 (0.69)	1.90 (0.74)	1.21 (0.89)	0.20 (0.40)
>9 pack-years	23 (16.08)	2.47 (0.71)	2.15 (0.78)	1.23 (1.05)	0.41 (0.76)
Present cooking fuel					
Biomass	57 (39.86)	2.07 (0.67) *	1.60 (0.72) *	0.92 (0.84)	0.16 (0.34) *
Kerosene	5 (3.50)	2.69 (0.76)	2.27 (0.77)	0.80 (1.03)	0.96 (1.28)
Gas	81 (56.64)	2.10 (0.76)	1.74 (0.78)	0.98 (0.85)	0.21 (0.40)
Heating fuel					
Wood	86 (60.14)	2.06 (0.70) *	1.64 (0.69) *	0.94 (0.84)	0.21 (0.47)
No heating fuel used	57 (39.86)	2.19 (0.78)	1.79 (0.86)	0.95 (0.88)	0.23 (0.44)
Ventilation in the kitchen					
Fully ventilated kitchen	113 (79.02)	2.14 (0.73)	1.74 (0.72) *	0.93 (0.87)	0.21 (0.40)
Unventilated kitchen	30 (20.98)	1.99 (0.73)	1.56 (0.89)	0.99 (0.81)	0.26 (0.62)
Source of light					

	N (%)	Mean score (standard deviation)			
		Nuclear Opacity ^a	Nuclear Color	Cortical Cataract	Posterior Sub-capsular Cataract
Electricity & solar lamp	141 (98.6)	2.12 (0.73) *	1.72 (0.76) *	0.95 (0.86)	0.22 (0.46)
Kerosene lamp	2 (1.40)	1.63 (0.79)	0.61 (0.15)	0.86 (0.66)	0.18 (0.24)
Work outside in the sun >1 hour daily					
Yes	92 (35.66)	2.09 (0.83)	1.78 (0.84)	0.91 (0.83)	0.22 (0.49)
No	51 (64.34)	2.12 (0.68)	1.66 (0.72)	1.00 (0.89)	0.21 (0.40)
Nutritional status					
Vegetarian	11 (7.69)	2.51 (0.71) *	2.16 (0.52) *	0.93 (0.64)	0.34 (0.54)
Non-vegetarian	132 (92.31)	2.08 (0.71)	1.67 (0.77)	0.95 (0.87)	0.21 (0.45)
Alcohol consumption					
Never	136 (95.10)	2.12 (0.74)	1.69 (0.77)	0.93 (0.85) *	0.21 (0.46)
Ever	7 (4.90)	1.95 (0.48)	1.90 (0.65)	1.30 (0.86)	0.33 (0.47)
Burn mosquito coil indoors					
Yes	53 (37.06)	2.02 (0.68)	1.50 (0.78) *	0.74 (0.68) *	0.21 (0.51)
No	90 (62.94)	2.17 (0.76)	1.83 (0.73)	1.06 (0.92)	0.23 (0.43)
Burn incense indoors					
Yes	130 (90.91)	2.07 (0.69) *	1.68 (0.75) *	0.91 (0.82) *	0.20 (0.43) *
No	13 (9.09)	2.48 (0.99)	1.90 (0.89)	1.27 (1.06)	0.45 (0.63)
Level of literacy					
Can read and write	72 (50.35)	1.89 (0.60) *	1.46 (0.68) *	0.78 (0.70) *	0.18 (0.35) *
Cannot read and write	71 (49.65)	2.34 (0.79)	1.93 (0.77)	1.12 (0.95)	0.30 (0.54)
Present occupation					
Farming on own land & Agriculture labor	50 (34.97)	2.15 (0.69) *	1.75 (0.71) *	0.97 (0.83)	0.20 (0.40) *
Non agriculture labor	7 (4.90)	1.88 (0.82)	1.23 (0.98)	0.36 (0.48)	0.51 (1.14)
Government services, commerce and business and teacher and student	23 (16.08)	1.74 (0.61)	1.42 (0.80)	1.04 (0.85)	0.19 (0.32)
Housewife	63 (44.06)	2.24 (0.75)	1.82 (0.73)	0.96 (0.89)	0.21 (0.40)
Land ownership					
Yes	102 (71.33)	2.07 (0.71) *	1.68 (0.74)	0.98 (0.84)	0.17 (0.34) *
No	41 (28.67)	2.21 (0.78)	1.77 (0.81)	0.87 (0.89)	0.33 (0.65)
Family annual income: Nepali Rupees[†]					
Rs. <=25,000	29 (21.17)	2.22 (0.75)	1.79 (0.81)	1.09 (0.93)	0.19 (0.36)

	N (%)	Mean score (standard deviation)			
		Nuclear Opacity ^a	Nuclear Color	Cortical Cataract	Posterior Sub-capsular Cataract
Rs. 25,000-50,000	48 (35.04)	2.02 (0.64)	1.66 (0.79)	0.88 (0.83)	0.25 (0.54)
Rs.50,000-100,000	39 (28.47)	2.06 (0.76)	1.66 (0.67)	0.88 (0.73)	0.16 (0.35)
Rs. >100,000	21 (14.69)	2.19 (0.75)	1.80 (0.85)	1.01 (0.97)	0.32 (0.53)
Declined to answer	6 (4.20)	2.40 (0.57)	1.62 (0.56)	0.97 (0.88)	0.18 (0.39)

* F-statistics for one-way ANOVA significant at p<0.05

^a Average of the consensus scores for the two eyes

[†] 1 US\$ ~ 73 NRs

Table 2

Characteristics of women with and without nuclear cataract (nuclear opacity LOCS III score ≥ 2), Pokhara, Nepal.

	Cataract (%) (N = 80)	No Cataract (%) (N=63)	Pearson Chi-square <i>P</i> value
Age in years			
20-29	3 (27.27)	8 (73.73)	0.00
30 - 39	10 (28.57)	25 (71.43)	
40 - 49	24 (54.55)	20 (45.45)	
50 +	43 (81.13)	10 (18.87)	
Religion			
Hindu	77 (56.62)	59 (43.38)	0.48
Buddhist	3 (42.86)	4 (57.14)	
Christian			
Residence locality			
Rural	10 (50.00)	10 (50.00)	0.56
Urban and Peri-urban	70 (56.91)	53 (43.09)	
Tobacco smoking			
Never	48 (48.98)	50 (51.02)	0.01
Ever	32 (71.11)	13 (28.89)	
Pack years of smoking			
0	46 (47.92)	50 (52.08)	0.01
>0 & 9 pack-years	15 (62.50)	9 (37.50)	
>9 pack-years	19 (82.61)	4 (17.39)	
Present cooking fuel			
Biomass	35 (61.40)	22 (38.60)	0.24
Kerosene	4 (80.00)	1 (20.00)	
Gas	41 (50.62)	40 (49.38)	
Heating fuel			
Wood	49 (56.98)	37 (43.02)	0.76
No heating fuel used	31 (54.39)	26 (45.61)	
Ventilation in the kitchen			
Fully ventilated kitchen	65 (57.52)	48 (42.48)	0.46
Unventilated kitchen	15 (50.00)	15 (50.00)	
Source of light			
Electricity & solar lamp	79 (56.03)	62 (43.97)	0.87
Kerosene lamp	1 (50.00)	1 (50.00)	
Work outside in the sun >1 hour daily			

	Cataract (%) (N = 80)	No Cataract (%) (N=63)	Pearson Chi-square <i>P</i> value
Yes	53 (57.61)	39 (42.39)	0.59
No	27 (52.94)	24 (47.06)	
Nutritional status			
Vegetarian	8 (72.73)	3 (27.27)	0.24
Non-vegetarian	72 (54.55)	60 (45.45)	
Alcohol consumption			
Never	77 (56.62)	59 (43.38)	0.48
Ever	3 (42.86)	4 (57.14)	
Burn mosquito coil indoors			
Yes	25 (47.17)	28 (52.83)	0.11
No	55 (61.11)	35 (38.89)	
Burn incense indoors			
Yes	72 (55.38)	58 (44.62)	0.67
No	8 (61.54)	5 (38.46)	
Literacy			
Can read and write	32 (44.44)	40 (55.56)	0.01
Cannot read and write	48 (67.61)	23 (32.39)	
Present occupation			
Farming on own land & Agriculture labor	31 (62.00)	19 (38.00)	0.12
Non agriculture labor	3 (42.86)	4 (57.14)	
Government services, commerce & business and teacher and student	8 (34.78)	15 (65.22)	
Housewife	38 (60.32)	25 (39.68)	
Land ownership			
Yes	56 (54.90)	46 (45.10)	0.69
No	24 (58.54)	17 (41.46)	
Family annual income: Nepali Rupees†			
Rs. <=25,000	19 (65.52)	10 (34.48)	0.46
Rs. 25,000-50,000	25 (52.08)	23 (47.92)	
Rs.50,000-100,000	20 (51.28)	19 (48.72)	
Rs. >100,000	11 (52.38)	10 (47.62)	
Declined to answer	5 (83.33)	1 (16.67)	

Table 3Multivariate logistic regression models for cataract (LOCS III score ≥ 2) in women, Pokhara, Nepal.

	Odds ratio (95% confidence interval)		
	Nuclear Opacity	Nuclear Color	Cortical Cataract
Present cooking fuel			
Gas	1.00	1.00	1.00
Biomass	2.58 (1.22; 5.46)	1.98 (0.82;4.74)	0.68 (0.19;2.39)
Kerosene	5.18 (0.88; 30.38)	5.48 (1.23; 24.37)	0.83 (0.12;5.55)
Heating fuel			
No heating fuel used	1.00	1.00	1.00
Wood	0.63 (0.32;1.25)	0.52 (0.23;1.17)	1.06 (0.42;2.68)
Ventilation in the kitchen			
Fully ventilated kitchen	1.00	1.00	1.00
Unventilated kitchen	0.34 (0.13; 0.89)	0.55 (0.21; 1.43)	0.49 (0.08;2.95)
Pack years of smoking			
0	1.00	1.00	1.00
>0 & ≤ 9 pack-years	1.57 (0.67;3.66)	1.34 (0.50;3.61)	1.82 (0.54;6.19)
>9 pack-years	2.55 (0.81; 8.00)	1.44 (0.52;3.98)	2.50 (0.64;9.74)
Burn mosquito coil indoors			
No		1.00	1.00
Yes		0.49 (0.22;1.09)	0.42 (0.09;1.81)
Nutritional status			
Non-vegetarian		1.00	
Vegetarian		1.45 (0.43;4.92)	
Residence locality			
Urban and Peri-urban		1.00	
Rural		0.31 (0.10;0.98)	
Land ownership			
Yes		1.00	
No		1.36 (0.57;3.24)	
Literacy			
Can read and write	1.00	1.00	1.00
Cannot read and write	0.66 (0.32;1.37)	1.08 (0.48;2.42)	1.41 (0.53; 3.73)
Present occupation			
Government services, commerce and business and teacher and student		1.00	1.00
Farming on own land & Agriculture labor		0.89 (0.26;2.97)	0.32 (0.04;2.28)
Non agriculture labor		0.35 (0.09;1.33)	
Housewife		0.67 (0.22;2.01)	0.37 (0.08;1.70)

	Odds ratio (95% confidence interval)		
	Nuclear Opacity	Nuclear Color	Cortical Cataract
Age in years			
20- 39	1.00	1.00	1.00
40 - 49	3.88 (1.84; 8.19)	8.76(2.80; 27.46)	8.30 (0.61; 113.49)
50 +	8.51 (3.79; 19.08)	86.72 (23.95; 314.01)	41.53 (3.85; 448.44)
Family annual income: Nepali Rupees			
Rs. >100,000			1.00
Rs. <=25, 000			1.84 (0.43;7.88)
Rs. 25,000-50,000			1.02 (0.25;4.18)
Rs. 50,000-100,000			0.53 (0.12;2.32)
Declined to answer			0.93 (0.16;5.59)
Pseudo R ²	0.17	0.41	0.25
Wald chi-square (<i>p</i> value)	37 (<0.001)	122 (<0.001)	34 (0.006)

Table 4

Exposure-response relationship for cataract (LOCS III score 2), based on duration of use of biomass fuel in women, Pokhara, Nepal

Duration of use of biomass fuel	n (%)	Odds ratio (95% confidence interval)		
		Nuclear Opacity ^a	Nuclear Color ^b	Cortical Cataract ^c
0 (never)	10 (6.99)	1.00	1.00	1.00
1 - 19 years	42 (29.37)	1.40 (0.62;3.12)	0.67 (0.20;2.29)	3.11 (0.48;22.07)
20-39 years	75 (52.45)	2.25 (0.93;5.42)	1.65 (0.48;5.70)	2.09 (0.29;14.96)
>40 years	16 (11.19)	4.29 (1.21;15.25)	5.43 (0.99;29.92)	4.31 (0.38;48.73)
P for trend	-	0.01	0.07	0.33

^a adjusted for: Heating fuel, ventilation in the kitchen, pack-years of smoking, literacy: cannot read & write and age categories

^b adjusted for: Heating fuel, ventilation in the kitchen, pack-years of smoking, nutritional status: vegetarian, land ownership, literacy: cannot read & write, residence locality, burn mosquito coil indoors, present occupation and age categories.

^c adjusted for: Heating fuel, ventilation in the kitchen, pack-years of smoking, literacy: cannot read & write, burn mosquito coil indoors, present occupation, annual family income and age categories.