Increasing prevalence of asthma in both developed and developing countries has been a major public health challenge for more than two decades (Anderson 1997; Platts-Mills and Woodfolk 1997; World Resources Institute 1998). Asthma is a chronic respiratory disease characterized by sudden attacks of labored breathing, chest tightness, and coughing. It is a complex multifactorial disease with both genetic and environmental components. A rapid increase in asthma in recent years cannot be ascribed to changes in local "neighborhood" pollution levels, with a number of health-damaging airborne pollutants, such as respirable particulate matter (≤ 10 µm in aerodynamic diameter (PM_{10})), carbon monoxide (CO), ozone (O_3), sulfur dioxide (SO_2), and nitrogen dioxide (NO_2), has been associated with increased asthma symptoms (Bald et al. 1999; Bates 1995; Castellsague et al. 1995; de Diego Damia et al. 1999; Greer et al. 1993; Hajat et al. 1999; Koren 1995; Zhang et al. 1999). In indoor environments, home bioallergens such as dust mites, molds, cockroach parts, and animal dander (Dales et al. 1991; Lewis et al. 2002; Litonjua et al. 1997; Rosenstreich et al. 1997; Thor et al. 2003; Togias et al. 1997; Weiss et al. 1993), and household cleaning agents, pesticides, and mosquito coil smoke (Azizi and Henry 1991; Azizi et al. 1995; Weiss et al. 1993) have been linked to increased risk of developing asthma. A number of lifestyle-related factors, such as outdoor activity and exercise, have also been associated with modifying asthma (Platts-Mills and Woodfolk 1997).

Numerous studies have suggested that exposure to tobacco smoke can increase the risk of developing asthma (Azizi and Henry 1991; Azizi et al. 1995; Flodin et al. 1995; Martinez et al. 1992; Strachan and Cook 1998; Thor et al. 2003). According to one estimate, children have about twice the risk of developing asthma if one or both parents smoke (NHLBI 1995). Several studies have found that exposure to tobacco smoke can increase the frequency and severity of attacks in asthmatics (Altshuis et al. 1999; Beeh et al. 2001; Eisner et al. 1998; Siouroux et al. 2000), but some fail to link tobacco smoking to onset of asthma in adults (Ben-Noun 1999; Siouroux et al. 2000; Vesterinen et al. 1998).

Much of the research on factors affecting asthma has been in urban areas of developed countries. In many homes in developing countries, however, a major source of exposure to indoor air pollutants is cooking smoke, when people rely on unprocessed biomass fuels such as wood, crop residues, and dung cakes for cooking and space heating. According to some estimates, more than half of the world’s population still relies on unprocessed biomass fuels for cooking and heating (Bruce et al. 2000). In the developing countries of South Asia and sub-Saharan Africa, this proportion is as high as 80% or more (Holdren and Smith 2000). These fuels are typically burned indoors in simple household cookstoves, such as a pit, three pieces of brick, or a U-shaped construction made from mud, which burn these fuels inefficiently and are often not vented with flues or hoods to take the pollutants to the outside. Even when the cookstoves are vented to the outside, combustion of unprocessed solid fuels produces enough pollution to significantly affect local "neighborhood" pollution levels, with implications for total exposures (Smith 2002).

Under these conditions, high volumes of a number of health-damaging airborne pollutants, including PM_{10}, CO, NOx, SO_2 (more from coal), formaldehyde, and dozens of toxic polycyclic aromatic hydrocarbons (e.g., benz(a)pyrene) and other organic matter, are generated indoors. Because cookstoves are usually used for several hours each day at times when people are present indoors, their exposure effectiveness is high; that is, the percentage of their emissions that reach people’s breathing zones is much higher than for outdoor sources. The individual peak and mean exposures experienced in such settings are...
often much greater than the safe levels recommended by the World Health Organization (WHO 1997). Bruce et al. (2000) compared typical levels of CO, PM$_{10}$, and PM$_{2.5}$ in homes in developing countries that use biomass fuels, with the U.S. Environmental Protection Agency’s standards for 24-hr average and concluded that indoor concentrations of these pollutants in homes that use biomass fuels usually exceed the guideline levels by several-fold. The poorest and most vulnerable populations in developing countries are most exposed to indoor air pollution from biomass combustion for cooking and heating. Exposure levels are usually much higher among women who tend to do most of the cooking (Behera et al. 1988) and among young children who are often held on their mother’s back or lap during cooking times (Albalak 1997). The elderly and the disabled also tend to stay indoors and therefore have higher exposure levels.

High exposures to air pollutants in biomass smoke have been associated with a host of respiratory diseases, including acute respiratory infections (Armstrong and Campbell 1991; Collings et al. 1990; Smith et al. 2000), chronic bronchitis (Albalak et al. 1999; Bruce et al. 1998; Pandey 1984), and tuberculosis (Mishra et al. 1999; Perez-Padilla et al. 2001). But the evidence on the effect of cooking smoke on asthma is mixed (Bruce et al. 2000), even though it contains some of the same pollutants that are found in ambient air pollution or tobacco smoke, both of which have been associated with asthma. Anecdotal association of asthma with cooking smoke is common, but few epidemiologic studies seem to have been done (Smith 2002). Of the limited research that does exist on this subject, some studies have found a positive association between cooking smoke and asthma (Mohammed et al. 1995; Pistelty 1997; Thorn et al. 2001; Xu et al. 1996), whereas others found no relationship (Azizi et al. 1995; Maier et al. 1997; Noorhassim et al. 1995; Qureshi 1994) or found a protective effect (Volkmer et al. 1995; von Mutius et al. 1996).

The mechanisms by which cooking smoke might influence asthma are not well understood. Air pollutants commonly found in biomass smoke have been associated with compromised pulmonary immune defense mechanisms in both animals and humans (Chang et al. 1990; Fujii et al. 2001; Green et al. 1977; Hardin et al. 1992; Kong et al. 1994; Mukae et al. 2001; Schnizlein et al. 1982; Tan et al. 2000; Taszakowski and Dwornicki 1992; van Eeden et al. 2001; Wang and Hu 1992; Zelikoff 1994). It is plausible that exposure to cooking smoke can impair pulmonary defense mechanisms and increase the risk of developing asthma or increase the frequency and severity of attacks in asthmatic people.

In this article I examine the effect of cooking smoke on the prevalence of asthma among the elderly in a developing country—India—using data from a nationally representative sample.

**Materials and Methods**

**Data.** Data are from India’s second National Family Health Survey (NFHS-2) conducted in 1998–1999. NFHS-2 collected demographic, socioeconomic, and health information from a nationally representative probability sample of 92,486 households. All states of India are represented in the sample, covering more than 99% of the country’s population. The sample is a multistage cluster sample with an overall response rate of 98%. Details of sample design, including sampling frame and sample implementation, are provided in the basic survey report for all India (IIPS and ORC Macro 2000). The analysis here is based on 38,595 persons 60 or more years old living in the sample households.

**Response variable.** The survey asked several questions relating to the current health status of household members, including whether each member suffered from asthma. The question was (referring to the listing of persons in the household) “Does anyone listed suffer from asthma?” The household head or other knowledgeable adult in the household reported for each household member. The survey was conducted using an interviewer-administered questionnaire in the native language of the respondent using a local, commonly understood term for asthma. A total of 18 languages were used in the survey. No effort was made to clinically test for the disease.

It is important to recognize that reported asthma is not as accurate as clinical measures of asthma. Because the disease carries a stigma, reported prevalence of asthma may be underestimated because of intentional concealment or lack of knowledge, especially for children and young adults. For the elderly, however, there is not much stigma attached to the disease and it is not considered contagious like tuberculosis, so underreporting due to intentional concealment should not be a major problem. There is also a possibility of overreporting because some other disease conditions with similar symptoms, such as chronic bronchitis or chronic obstructive pulmonary disease, may be reported as asthma.

In India, where clinical data on asthma are mostly unavailable or very weak, this reported prevalence of asthma from a representative national sample provides a unique opportunity to examine the factors associated with asthma prevalence among the elderly. In our analysis, this reported prevalence of asthma is the response variable.

**Predictor variables.** Exposure to cooking smoke is ascertained indirectly by type of fuel used for cooking or heating. The survey used a 10-item classification of cooking fuel: wood, crop residues, dung cakes, coal/coke/lignite, charcoal, kerosene, electricity, liquid petroleum gas, biogas, and a residual category of other fuels. The question was “What type of fuel does your household mainly use for cooking?” followed by the above list of fuels. The survey also included a second question, “What other types of fuel does your household commonly use for cooking or heating?” with the same 10-item classification of fuels.

This second question was a multiple response question, meaning a respondent could choose more than one fuel. We used information from these questions to group households into three categories representing the extent of exposure to cooking smoke—high-exposure group (households using only biomass fuels: wood, crop residues, or dung cakes), low-exposure group (households using only cleaner fuels: kerosene, petroleum gas, biogas, or electricity), and medium-exposure group (a mix of biomass fuels and cleaner fuels or coal/coke/lignite/charcoal). This three-category classification of fuels is the principal predictor variable.

The survey also collected information on tobacco smoking (both current and lifetime) for each household member. For all persons in the sampled households, the NFHS-2 asked “Does anyone listed smoke?” For current nonsmokers, the survey asked “Has any (other) person listed ever smoked regularly?” The information from these two questions was used to ascertain exposure to tobacco smoke—active smoking (person currently smokes or has smoked regularly in the past), passive smoking (one or more other persons in the household smoke currently), no smoking (the person has never smoked regularly and no other person in the household smokes currently).

Because the effects of exposure to cooking smoke as well as tobacco smoke on the prevalence of asthma are likely to be confounded with the effects of other risk factors, it is necessary to statistically control, or adjust, for such factors. Control variables included in this study were age, sex, marital status, education, religion of household head, caste/tribe of household head, house type, availability of a separate kitchen in the house, crowding in the household, living standard of the household, urban/rural residence, and geographic region. For definition of variables, see Table 1.

**Analysis.** Because our response variable—prevalence of asthma—is dichotomous, we use logistic regression to estimate the effects of cooking smoke (from biomass fuel use relative to cleaner fuel use) and tobacco smoke (both active and passive) on asthma prevalence with
the other 12 demographic and socioeconomic variables mentioned above as controls. Because of large sex differentials in the exposure to cooking smoke and tobacco smoke, the analysis is also carried out separately for men and women. Results are presented in the form of odds ratios (ORs) with 95% confidence intervals (95% CI). The estimate of confidence intervals takes into account design effects due to clustering at the level of the primary sampling unit. The logistic regression models were estimated using the STATA statistical software package (Stata Corporation 2001).

Before carrying out the multivariate models, we tested for the possibility of multicollinearity between the predictor variables. In the correlation matrix of predictor variables, all pairwise Pearson correlation coefficients are < 0.5, suggesting that multicollinearity is not a problem. In the survey, certain states and certain categories of households were oversampled. In all our analysis, weights are used to restore the representativeness of the sample (IIPS and ORC Macro 2000).

Results

Profile of the elderly. According to the NFHS-2, about 8% of India’s population is ≥ 60 years old (IIPS and ORC Macro 2000). Table 1 shows the distribution of elderly people by selected background characteristics. Fifty-nine percent of the elderly live in households using biomass fuels (wood, dung cakes, or crop residues), 15% live in households using cleaner fuels (kerosene, liquid petroleum gas, biogas, or electricity), and the remaining 26% live in households that use a mix of biomass fuels and cleaner fuels or coal/coke/lignite or charcoal. Forty-seven percent of elderly men and 6% of elderly women currently smoke tobacco or have smoked regularly in the past. Another 10% of men and 36% of elderly women live in households where someone else smokes.

The proportion of elderly declines by age, as expected. Sixty-two percent are currently married (81% of men and 41% of women). About two-thirds are illiterate, and only 12% have middle school or higher education. The proportion illiterate is much higher for women than for men (82% and 50%, respectively), as expected. Distribution by religion and caste/tribe resembles that in the total population, with a little more than four out of five elderly belonging to Hindu religion and one out of four belonging to a scheduled caste or scheduled tribe. About one-third live in pucca (higher-quality) houses, about one-half live in houses without a separate kitchen, and more than one-third live in houses with three or more persons per room. Two of five live in households with a low standard of living, and one of five lives in a household with a high standard of living. Three of four live in rural areas, and one of two lives in the central and east region.

Prevalence of asthma among the elderly. Asthma is a serious problem among the elderly in India. According to the NFHS-2, one of every 10 people ≥ 60 years old suffers from asthma (IIPS and ORC Macro 2000). Table 2 shows that the prevalence of asthma is higher among elderly men than among elderly women and higher in rural areas than in urban areas. By type of cooking fuel, elderly living in households using biomass

| Characteristic | Male | Female | Total |
|---------------|------|--------|-------|
| Cooking smoke* | Biomass fuels | 59.6 | 56.7 | 58.7 |
|                | Fuel mix | 25.8 | 27.0 | 26.4 |
|                | Cleaner fuel | 14.6 | 15.4 | 14.9 |
| Tobacco smoke  | Active smoking | 46.8 | 6.0 | 27.4 |
|                | Passive smoking | 9.7 | 36.3 | 22.4 |
|                | No smoking | 43.5 | 57.7 | 50.2 |
| Age            | 60–64 | 35.7 | 38.9 | 37.2 |
|                | 65–69 | 24.5 | 25.7 | 25.0 |
|                | 70–74 | 21.0 | 17.7 | 19.4 |
|                | ≥ 75  | 18.8 | 17.7 | 18.3 |
| Marital status | Currently married | 81.3 | 40.6 | 62.0 |
|                | Not married | 18.7 | 59.4 | 38.0 |
| Education      | Illiterate | 49.8 | 82.3 | 65.3 |
|                | Literate, < middle completed | 31.5 | 13.6 | 23.0 |
|                | Middle completed or higher | 18.7 | 4.0 | 11.7 |
| Religion       | Hindu | 82.5 | 82.7 | 82.6 |
|                | Muslim | 10.7 | 10.6 | 10.7 |
|                | Other* | 6.8 | 6.7 | 6.8 |
|                | Castes/tribes | 26.5 | 25.4 | 26.0 |
|                | Scheduled caste/scheduled tribe | 73.5 | 74.6 | 74.0 |
|                | House type* | 31.6 | 33.3 | 32.4 |
|                | Pucca | 36.2 | 35.7 | 36.0 |
|                | Semi-pucca | 32.1 | 31.0 | 31.6 |
|                | Kachha | 55.0 | 55.7 | 55.3 |
|                | Yes | 45.0 | 44.3 | 44.7 |
|                | No | 36.3 | 35.8 | 36.1 |
| Standard of living* | Low | 40.6 | 42.3 | 41.4 |
|                | Medium | 39.7 | 37.8 | 38.8 |
|                | High | 19.8 | 20.0 | 19.9 |
| Residence      | Urban | 23.3 | 25.2 | 24.2 |
|                | Rural | 76.7 | 74.9 | 75.8 |
| Region*        | North and Northeast | 4.1 | 3.6 | 3.9 |
|                | Central and East | 52.8 | 49.5 | 51.2 |
|                | West | 18.7 | 20.6 | 19.6 |
|                | South | 24.3 | 26.3 | 25.3 |
| Number of elderly* | 20,418 | 18,177 | 38,595 |

*Biomass fuels: wood, dung, or crop residues; fuel mix: mix of biomass and cleaner fuels or coal/coke/lignite; cleaner fuel: kerosene, petroleum gas, biogas, or electricity. *Sikh, Buddhist, Christian, Jain, Jewish, Zoroastrian. *Castes and tribes identified by the Government of India as socially and economically backward and needing protection from social injustice and exploitation. *Pucca houses are made from high-quality materials (bricks, tiles, cement, and concrete) throughout, including roof, walls, and floor; kachha houses are made from mud, thatch, or other low-quality materials. Semi-pucca houses are made from a combination. *Standard of living index is calculated by adding the scores assigned to the durable goods in the household as following: 4 for a car or tractor; 3 each for a moped/scooter/motorcycle, telephone, refrigerator, or color television; 2 each for a bicycle, electric fan, radio/television; and 1 each for a mattress, pressure cooker, chair, cot/bed, table, or clock/watch. Index scores range from 0–5 for low SLI, 6–15 for medium SLI, to 16–42 for high SLI. *North and northeast: Jammu, Kashmir, Himachal Pradesh, Assam, Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura; central and east: Haryana, Punjab, Delhi, Uttar Pradesh, Madhya Pradesh, Bihar, West Bengal, Orissa; west: Maharashtra, Goa, Gujarat, Rajasthan; south: Andhra Pradesh, Karnataka, Kerala, Tamil Nadu. *Number of elderly varies slightly for individual variables depending on the number of missing values.
fueled are about two times more likely to suffer from asthma (11.9%) than are those living in households using cleaner fuels (6.6%). Elderly who smoke (or have ever smoked regularly in the past) are also much more likely to suffer from asthma than are those who have never smoked. Elderly who middle school or more education are less likely to suffer from asthma than are those with less or no education. The prevalence of asthma is considerably lower among the elderly living in households with a separate kitchen and among elderly living in households with a high standard of living. The prevalence is also somewhat lower among elderly living in pucca houses and among those living in houses with fewer than three persons per room. The prevalence does not vary much by other characteristics. Differentials in the prevalence of asthma by sex are similar to those discussed above for both men and women combined.

**Effects of cooking smoke on asthma.** Table 3 shows the estimated effects of cooking smoke, tobacco smoke, and selected demographic and socioeconomic variables on the prevalence of asthma among the elderly (> 60 years old) in alternative models. Model 1 in Table 3 shows that unadjusted odds of suffering from asthma are almost two times higher among the elderly living in households using biomass fuels for cooking than among those living in households using cleaner fuels for cooking (OR = 1.92; 95% CI, 1.67–2.19). Elderly living in households using a mix of biomass fuels and cleaner fuels or coal/coke/lignite or charcoal are also at a considerably higher risk of suffering from asthma (OR = 1.40; 95% CI, 1.21–1.62). Controlling for exposure to tobacco smoke (in Model 3) reduces the effect of biomass fuel use on asthma prevalence slightly (OR = 1.75; 95% CI, 1.53–2.01). The effect of biomass fuel use remains virtually unchanged when the two demographic variables—age and sex—are additionally controlled in Model 4. Even when the 10 socioeconomic control variables are included in Model 5, cooking with biomass fuels still has a large and statistically significant effect (OR = 1.59; 95% CI, 1.30–1.94) on the prevalence of asthma among the elderly. In the full model (Model 5), the elderly living in households using a mix of biomass and cleaner fuels or coal/coke/lignite or charcoal also have a significantly higher risk of suffering from asthma compared to those living in households that use cleaner fuels (OR = 1.24; 95% CI, 1.04–1.49).

**Effects of tobacco smoke on asthma.** Elderly men and women who currently smoke tobacco or have ever smoked regularly in the past are at a considerably higher risk of suffering from asthma (OR = 1.79; 95% CI, 1.63–1.96) than do those who have never smoked and do not live in a household with other smokers (Model 2, Table 3). This effect is reduced somewhat when the effect of cooking smoke is controlled (OR = 1.66; 95% CI, 1.51–1.82) and reduced further when respondent’s age and sex are additionally controlled (OR = 1.54; 95% CI, 1.39–1.71). In the full model (Model 5), when the effects of cooking fuel type and the 12 other variables are controlled, the odds of suffering from asthma are 1.55 (95% CI, 1.39–1.73) times higher among the elderly who are current smokers or have ever smoked regularly than among those who have never smoked tobacco regularly and do not live in a household with other smokers. Passive smoking does not seem to have any significant effect on the risk of asthma among the elderly. Elderly men and women who have never smoked tobacco regularly but who live in households where other household members smoke are about as likely to suffer from asthma as those who never smoked who live in households where no one else smokes (OR = 1.09; 95% CI, 0.97–1.22).

**Effects of the control variables on asthma.** The discussion of the adjusted effects of the control variables focuses on the full model (Model 5) in Table 3. With other variables controlled, age has a positive effect on the prevalence of asthma and women have a considerably lower prevalence of asthma than do men. Effects of both age and sex are statistically significant. Elderly men and women with middle school or higher education have significantly lower prevalence of asthma than do those with less or no education. As expected, elderly living in households with a separate kitchen have a significantly lower prevalence of asthma than do those living in households without a separate kitchen. Also as expected, household living standard has a significant negative effect on asthma prevalence among the elderly. However, contrary to the expectation, elderly living in higher-quality (pucca) housing have a significantly higher risk of asthma do than those living in kachha (lower-quality) houses. Crowding within the house also has a negative effect on the prevalence of asthma, but the effect of crowding is not significant statistically.

With other variables controlled, the prevalence of asthma among the elderly does not vary significantly by urban/rural residence. Marital status of the elderly at the time of the survey, religion, and membership in a scheduled caste or scheduled tribe also do not have significant effects on asthma prevalence in the elderly. By geographic region, elderly in the western region have significantly higher prevalence of asthma than do those in other regions.

**Sex differences in effects.** Because women tend to do the cooking and are much more exposed than men to cooking smoke, because men are much more likely than women to smoke tobacco, and because there are sex differences in nutritional status, susceptibility to disease, and access to treatment and care, the effects of cooking smoke on asthma are likely to vary by sex. To examine this, we repeated the above analysis separately for men and women. Only adjusted effects in full models are presented in Table 4.

The adjusted effect of exposure to cooking smoke (biomass fuel use relative to cleaner fuel use) on the prevalence of asthma is large and statistically significant for both men and women.
elderly men and women. The adjusted effect is larger for women (OR = 1.83; 95% CI, 1.32–2.53) than for men (OR = 1.46; 95% CI, 1.14–1.88). Elderly women in households using a mix of biomass and cleaner fuels also have significantly higher asthma prevalence than those in households using only cleaner fuels (OR = 1.48; 95% CI, 1.12–1.97), but this adjusted effect of fuel mix for elderly men is small and not statistically significant (OR = 1.12; 95% CI, 0.89–1.41). The adjusted effects of active tobacco smoking (ever smoked tobacco regularly) on asthma are also large and statistically significant for both men and women. Again, the effect is larger for women (OR = 1.89; 95% CI, 1.49–2.39) than for men (OR = 1.50; 95% CI, 1.33–1.69). Adjusted effects of passive smoking (others in the household smoke) are much smaller for men and women and statistically not significant.

With the effects of cooking smoke, tobacco smoking, and other variables controlled, only age, household living standard, and geographic region have significant effects on asthma prevalence for both men and women. Availability of a separate kitchen has a significant negative effect on asthma prevalence in men, but this effect is relatively small and not statistically significant for women. Education has a significant negative effect for men, but for women the relationship is reversed and the effect is not statistically significant. Both elderly men and women in pucca houses have higher prevalence of asthma than those living in kachha houses, but these effects are also not significant. Effects of all other control variables are small and not significant statistically.

### Discussion

Results from this study suggest that exposure to cooking smoke is strongly associated with the prevalence of asthma among elderly men and women, independent of exposure to tobacco smoke, age, education, living standard, and other factors. Active tobacco smoking also has substantial effects, but passive smoking tends not to have any significant effect. Effects of both cooking smoke and tobacco smoke are greater for women than for men.

The finding that the effect of cooking smoke is greater for women than for men is consistent with expectation, because women are more exposed than men to cooking smoke. However, given the relatively low status of women in India, asthma may be less likely to be reported for women than for men, especially in households that use biomass fuels for cooking. For this reason, the sex differential in the effect of cooking smoke on asthma may be greater than indicated by our analysis. A larger effect of tobacco smoking in women than in men may reflect greater vulnerability of women because of their compromised respiratory system from cooking smoke, poorer nutritional status, and less access to treatment and care compared with men. A larger negative effect of availability of a separate kitchen for men than for women is consistent with expectation because availability of a separate kitchen in the household is more likely to reduce cooking smoke exposures in men than in women, who do much of the cooking.

To the extent that the effect of cooking smoke on asthma is cumulative over time, previous shifts from biomass fuels to cleaner fuels tend to downwardly bias our estimates of the effect. Our estimated effect is also downwardly biased to the extent that asthma is more likely to be underreported for persons from households that use biomass fuels. On the other hand, our estimated effect may be upwardly biased to the extent that households that use biomass fuels are more likely to report some other disease condition with similar symptoms as asthma. To the extent that this happens, our results represent the association of biomass combustion with chronic respiratory symptoms as asthma. To the extent that this happens, our results represent the association of biomass combustion with chronic respiratory symptoms as asthma.

### Table 3. Unadjusted and adjusted effects (OR, 95% CI) of cooking smoke, tobacco smoke, and other factors on asthma among the elderly (≥60 years old), India 1998–1999.

| Characteristic                  | Model 1     | Model 2     | Model 3     | Model 4     | Model 5     |
|--------------------------------|-------------|-------------|-------------|-------------|-------------|
| **Cooking smoke**              |             |             |             |             |             |
| Biomass fuels                  | 1.92 (1.67, 2.19) | 1.75 (1.53, 2.01) | 1.77 (1.54, 2.34) | 1.59 (1.30, 1.94) |
| Cleaner fuel<sup>a</sup>        | 1.40 (1.21, 1.62) | 1.32 (1.14, 1.53) | 1.32 (1.14, 1.53) | 1.24 (1.04, 1.49) |
| Tobacco smoke                  |             |             |             |             |             |
| Active smoking                 | 1.79 (1.63, 1.96) | 1.66 (1.51, 1.82) | 1.54 (1.39, 1.71) | 1.55 (1.39, 1.73) |
| Passive smoking                | 1.10 (0.99, 1.22) | 1.03 (0.93, 1.15) | 1.08 (0.97, 1.20) | 1.09 (0.97, 1.22) |
| No smoking<sup>b</sup>         |             |             |             |             |             |
| **Age**                        |             |             |             |             |             |
| 60–64<sup>a</sup>              |             |             |             |             |             |
| 65–69                          | 1.25 (1.12, 1.38) | 1.22 (1.10, 1.36) |             |             |
| 70–74                          | 1.53 (1.37, 1.71) | 1.52 (1.35, 1.70) |             |             |
| ≥ 75                           | 1.54 (1.37, 1.73) | 1.51 (1.33, 1.71) |             |             |
| **Sex**                        |             |             |             |             |             |
| Male<sup>a</sup>               |             |             |             |             |             |
| Female                         | 0.83 (0.75, 0.91) | 0.80 (0.71, 0.89) |             |             |
| **Marital status**             |             |             |             |             |             |
| Currently married              |             |             |             |             |             |
| Not married<sup>a</sup>        |             |             |             |             |             |
| **Education**                  |             |             |             |             |             |
| Illiterate<sup>a</sup>         |             |             |             |             |             |
| Literate, < middle completed   | 1.03 (0.92, 1.16) |             |             |             |
| Middle completed or higher     | 0.83 (0.70, 0.98) |             |             |             |
| **Religion**                   |             |             |             |             |             |
| Hindu<sup>a</sup>              |             |             |             |             |             |
| Muslim                         | 0.97 (0.82, 1.15) |             |             |             |
| Other                           | 1.02 (0.84, 1.22) |             |             |             |
| **Caste/tribe**                |             |             |             |             |             |
| Scheduled caste/scheduled tribe|             |             |             |             |             |
| Other<sup>a</sup>              | 0.96 (0.87, 1.63) |             |             |             |
| **House type**                 |             |             |             |             |             |
| Pucca                          |             |             |             |             |             |
| Semi-pucca                     | 1.17 (1.03, 1.34) |             |             |             |
| Kachha<sup>a</sup>             | 1.03 (0.93, 1.15) |             |             |             |
| **Separate kitchen**           |             |             |             |             |             |
| Yes                             | 0.83 (0.75, 0.92) |             |             |             |
| No<sup>a</sup>                 |             |             |             |             |             |
| **Crowding**                   |             |             |             |             |             |
| < 3 persons per room<sup>a</sup> |             |             |             |             |             |
| ≥ 3 persons per room           | 0.93 (0.85, 1.03) |             |             |             |
| **Standard of living**         |             |             |             |             |             |
| Low<sup>a</sup>                |             |             |             |             |             |
| Medium                         | 0.89 (0.80, 0.98) |             |             |             |
| High                           | 0.75 (0.63, 0.88) |             |             |             |
| **Residence**                  |             |             |             |             |             |
| Urban                          |             |             |             |             |             |
| Rural<sup>a</sup>              |             |             |             |             |             |
| **Region**                     |             |             |             |             |             |
| North and Northeast            | 0.98 (0.83, 1.19) |             |             |             |
| Central and East               | 1.04 (0.92, 1.19) |             |             |             |
| West                           | 1.37 (1.18, 1.59) |             |             |             |
| South<sup>a</sup>              |             |             |             |             |             |
| **Number of elderly**          |             |             |             |             |             |
| 38,389                         |             |             |             |             |             |
| 38,549                         |             |             |             |             |             |
| 38,297                         |             |             |             |             |             |
| 38,297                         |             |             |             |             |             |
| 36,520                         |             |             |             |             |             |

For variable definitions, see Table 1.

*Reference category.
disorders in elderly Indians, including asthma. In cases where asthma might have been confused with some other chronic respiratory disorder, it is not possible from our data to separate the effect on asthma from the effect on some other condition with similar symptoms. Moreover, we are not able to control directly for extent of use of medical services in connection with asthma, although our set of control variables includes several measures of socioeconomic status, which is correlated with access to and use of medical services. Well-designed epidemiological studies with better measures of smoke exposure and clinical measures of asthma are needed to validate the findings of this study and to better understand the pathogenesis of asthma.

The findings from this study have important policy and program implications, including the need for public information campaigns designed to inform people about the risks of exposure to cooking smoke and, where shifts to cleaner fuels are not feasible, programs to promote improved cookstoves designed to reduce exposure to smoke by means of improved combustion and improved venting. For such programs to be effective, local needs and community participation should be given high priority. Programs to reduce exposure to tobacco smoke should be promoted, in addition to strengthening asthma prevention and treatment programs.

### Table 4. Adjusted effects (OR, 95% CI) of cooking smoke, tobacco smoke, and other factors on asthma among the elderly (≥ 60 years old) by sex, India, 1998–1999

| Characteristic                      | Male                  | Female                |
|-------------------------------------|-----------------------|-----------------------|
| Cooking smoke                       |                       |                       |
| biomass fuels                       | 1.46 (1.14, 1.88)     | 1.83 (1.32, 2.53)     |
| Fuel mix                            | 1.12 (0.89, 1.41)     | 1.48 (1.12, 1.97)     |
| Cleaner fuel*                       |                       |                       |
| Tobacco smoke                       |                       |                       |
| Active smoking                      | 1.50 (1.33, 1.69)     | 1.89 (1.49, 2.39)     |
| Passive smoking                     | 1.20 (0.93, 1.49)     | 1.05 (0.91, 1.21)     |
| No smoking*                         |                       |                       |
| Age                                 |                       |                       |
| 60–64                               |                       |                       |
| 65–69                               | 1.35 (1.17, 1.57)     | 1.06 (0.90, 1.26)     |
| ≥ 70–74                             | 1.68 (1.44, 1.93)     | 1.32 (1.09, 1.60)     |
| ≥ 75                                | 1.57 (1.34, 1.85)     | 1.42 (1.18, 1.71)     |
| Marital status                      |                       |                       |
| Currently married                   | 0.90 (0.78, 1.03)     | 0.97 (0.84, 1.12)     |
| Not married†                        |                       |                       |
| Education illiterate                |                       |                       |
| Literate, < middle completed        | 0.99 (0.87, 1.12)     | 1.17 (0.92, 1.45)     |
| Middle completed or higher          | 0.77 (0.74, 0.93)     | 1.18 (0.78, 1.77)     |
| Religion                            |                       |                       |
| Hindu†                              |                       |                       |
| Muslim                              | 0.94 (0.76, 1.15)     | 1.03 (0.80, 1.32)     |
| Other†                              | 0.97 (0.77, 1.20)     | 1.05 (0.81, 1.38)     |
| Caste/tribe                         |                       |                       |
| Scheduled caste/scheduled tribe     | 0.96 (0.84, 1.09)     | 0.96 (0.82, 1.12)     |
| Other‡                              |                       |                       |
| House type                          |                       |                       |
| Pucca                               | 1.16 (0.97, 1.38)     | 1.20 (0.99, 1.46)     |
| Semi-pucca                          | 1.05 (0.92, 1.20)     | 1.02 (0.86, 1.21)     |
| Kachha†                             |                       |                       |
| Separate kitchen                    | 0.81 (0.72, 0.93)     | 0.86 (0.75, 1.00)     |
| Yes†                                |                       |                       |
| No‡                                 |                       |                       |
| Crowding                            |                       |                       |
| < 3 persons per room‡               | 0.91 (0.81, 1.02)     | 0.97 (0.83, 1.12)     |
| ≥ 3 persons per room‡               |                       |                       |
| Standard of living                  |                       |                       |
| Low‡                                |                       |                       |
| Medium                              | 0.95 (0.94, 1.08)     | 0.79 (0.67, 0.92)     |
| High                                | 0.72 (0.58, 0.89)     | 0.76 (0.59, 0.98)     |
| Residence                           |                       |                       |
| Urban‡                              | 1.09 (0.91, 1.30)     | 1.00 (0.80, 1.23)     |
| Rural‡                              |                       |                       |
| Region                              |                       |                       |
| North and Northeast                 | 0.88 (0.69, 1.09)     | 1.19 (0.91, 1.54)     |
| Central and East                    | 0.98 (0.83, 1.15)     | 1.14 (0.95, 1.37)     |
| West†                               | 1.25 (1.04, 1.45)     | 1.56 (1.26, 1.92)     |
| South‡                              |                       |                       |
| Number of elderly                   | 19,329                | 17,191                |

*Reference category.

**For variable definitions see Table 1.**
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