

**DRAFT**

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**GENDER ASPECTS OF INDOOR AIR POLLUTION AND HEALTH: AN ANALYSIS  
OF GENDER DIFFERENTIALS IN THE EFFECT OF COOKING SMOKE ON ACUTE  
RESPIRATORY INFECTIONS IN CHILDREN**

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## **ABSTRACT**

*Cooking smoke, like cigarette smoke, has been shown to have major health effects. Differences in gender roles result in differential exposures to cooking smoke among males and females. Moreover, gender differences in nutritional status, treatment, and care, as well as genetic and biological differences between the two sexes, result in differential effects of these exposures on males and females. Analysis of data from India's 1992-93 National Family Health Survey shows that the prevalence of acute respiratory infections (ARI) is more than 50 percent higher among children from biomass-fuel-using households than among those from cleaner-fuel-using households. The prevalence of ARI is considerably higher among boys than among girls. The effect of biomass fuel use on the prevalence of ARI is also higher for boys than for girls. This may be due, in part, to greater underreporting of ARI for girls and greater underreporting for girls in biomass-fuel-using households. Higher ARI rate and greater effect of cooking smoke among boys may also occur because mothers in India are more likely to carry young boys than girls or keep them in the kitchen area while cooking. The results hold even after statistically controlling for several potentially confounding socioeconomic factors.*

## INTRODUCTION

As a result of the household use of unprocessed biomass fuels in developing countries, concentrations of health-damaging air pollutants tend to be highest indoors, where biomass fuels such as wood, animal dung, and crop residues are burned by many households for cooking and heating (Smith 1996a). This is contrary to the common perception that air pollution is primarily an urban phenomenon associated with motor vehicles and industries. A large proportion of households in developing countries rely on biomass fuels for cooking and space heating, and biomass will continue to be the primary source of household energy in developing countries in the foreseeable future. As a result, some 3.5 billion people are exposed to high levels of air pollutants at their homes, mostly in the rural areas of developing countries. Indoor air pollution from cooking and heating with traditional fuels has been designated by the World Bank as one of the four most critical environmental problems in developing countries (World Bank 1992). Although overall use of biomass fuel as a source of energy is projected to decline slowly over the years, the reliance on biomass as percent of total energy use will remain quite substantial (Figure 1) (World Bank 1996; WRI 1998; WEC 1999). Lower-income countries depend much more on biofuels than do rich countries, and reliance on biofuels for household energy may have actually increased recently in some poor areas of developing countries (WRI 1998).

<Figure 1 about here>

Table 1 shows that observed levels of indoor particulate concentrations ( $\mu\text{g m}^{-3}$ ) from biomass burning are extremely high in many parts of the developing world. Daily average exposures often far exceed safe levels recommended by the World Health Organization (WHO 1997a).

<Table 1 about here>

A major component of environmental risk transition in developing countries has traditionally been the decline in household environmental risks in the form of contaminated food, water, and air. In the case of air quality, this has historically been accomplished through movement up the “energy ladder” from the relatively polluting biomass fuels—e.g., wood, dung, and crop residues—to the cleaner liquid and gaseous fuels and, in some cases, electricity for cooking (Smith 1990a, 1990b). Biomass fuels are at the high end of the fuel ladder in terms of air pollution, and at the low end in terms of combustion efficiency (Smith and Liu 1994). The proportion of households using biomass fuels as primary source of energy for cooking and heating declines considerably as household income increases. Although it is clear that typical pollution exposures decline dramatically in the switch from traditional unprocessed biomass fuels to modern fuels, the role of this transition in the overall epidemiologic transition is not fully understood (Smith 1996a).

Biomass smoke contains many noxious components, including respirable particulates, carbon monoxide, nitrogen oxides, formaldehyde, and polycyclic aromatic hydrocarbons such as benzo(a)pyrene (WHO 1992; Smith 1987; Smith 1993). High exposures to these air pollutants have been shown to cause serious health problems, such as acute respiratory infections, chronic obstructive lung disease, cor pulmonale, tuberculosis, blindness, and lung cancer (de Koning et al. 1985; Kossove 1982; Pandey et al. 1989; Collings et al. 1990; Armstrong and Campbell 1991;

Malik 1985; Pandey 1984; Behera and Jindal 1991; Perez-Padilla et al. 1996; Mishra and Retherford 1997; Pandey et al. 1988; Bruce et al. 1998; Dennis et al. 1996; Padmavati and Arora 1976; Dhar and Pathania 1991; Sandoval et al. 1993; Mishra et al. 1999a, 1999b, 2000; Sobue 1990; Sun 1992; Pintos et al. 1998). Exposure to cooking smoke has also been linked to pregnancy outcomes, low birth weight, and perinatal mortality (Mavalankar et al. 1991; Wang et al. 1997). A good review of various health effects of indoor air pollution can be found in Bruce et al. (2000).

Globally, combustion of solid household fuels accounts for an estimated 2.5 million premature deaths annually (WHO 1997). In other words, health impact of dirty household air is similar in magnitude to contaminated water at the household level, about 6-7 percent of the global burden of disease (McMichael and Smith 1999)—considerably more than the 0.5 percent due to urban ambient air pollution (Murray and Lopez 1996). Overall, it has been estimated that 25-33 percent of the global burden of disease can be attributed to environmental risk factors, of which indoor air pollution is a major factor (Smith et al. 1999). A recent study puts solid fuel use as the third largest risk factor, after malnutrition and water/hygiene/sanitation, in causing disability and death in developing countries (Smith and Mehta 2000).

This paper is divided into two sections. First, it reviews gender aspects of effects of indoor air pollution from cooking smoke on health in developing countries. Second, it examines gender differentials in the effects of cooking smoke from biomass fuels on acute respiratory infections (ARI) among young children.

## **GENDER ASPECTS OF IAP AND HEALTH: AN OVERVIEW**

Poor women in rural areas of developing countries are the primary collectors and users of biomass fuels, fodder, water, and other natural resources for household consumption. Due to their roles in these subsistence activities and closer proximity to the environment, women bear a disproportionate burden of deteriorating environmental conditions, including deforestation and loss of common property resources (Cecelski 1995; United Nations 1995; Agarwal 1986, 1995). In many poor countries in South Asia and Africa women and girls spend several hours each day fetching fuelwood or animal dung for cooking and space heating (United Nations 1995; WEC 1999). Because biofuels are very inefficient source of energy, women need to collect large quantities of these fuels and need to carry them long distances. Women's role as primary collectors, carriers, and users of biofuels has implications for their school attendance, childcare, and health.

In most countries, women usually work more hours than men, and unpaid household work dominates women's time. In South Asia, women work anywhere from about 7 to 21 hours per week more than men (Table 2). Cooking accounts for a large share of women's household work, and compared with men, women contribute 75 percent or more to cooking activities in most countries. The good news is that the gender gap in time spent on cooking is narrowing somewhat. According to a study in 21 countries (mostly developed), the average time women spend cooking declined from about 90 minutes per day in 1961 to about 60 minutes in 1992.

During the same period, the average time that men spend cooking increased slightly from about 15 minutes to about 20 minutes (United Nations 1995).

<Table 2 about here>

There is evidence that men typically spend much less time in the kitchen area than women. In a study in the Himalayan foothills in India, men spent little time in the kitchen area and considerably more time outdoors and away from the village than women. Consequently, women had much higher levels of exposure to TSP ( $\text{mg m}^{-3}$ )<sup>1</sup> and CO (ppm)<sup>2</sup> than men (Saxena et al. 1992). Another study of exposure to particulates from cooking with biomass fuels in two Bolivian highland villages also recorded that men spend relatively less time in the kitchen area, but there was little difference in the time spent indoors or outdoors by gender. Although, women recorded higher levels of daily exposure to particulate matter (PM<sub>10</sub>)<sup>3</sup> in each village and in each season, the differences between men and women were not large (Albalak et al. 1999).

Due to the very fact that women do much of the cooking, especially among biomass-fuel-using households, they are also more prone to fires and burns than men.

Men's and women's bodies respond differently to different pollutants. For example, carbon monoxide (CO), a major component of biomass smoke, is a pollutant of particular concern to women. CO acts by displacing oxygen in the hemoglobin of the blood to make carboxyhemoglobin (HbCO), effectively reducing the amount of oxygen reaching the body tissues (Smith 1996b). Women generally have less hemoglobin in reserve than men and are naturally more prone to anemia than men. Also, negative impacts of CO in women may occur at lower doses than would be the case for men. During pregnancy, women naturally produce more CO internally and the natural rate of internal CO production can be up to 50 percent higher than their normal level. As a consequence, women have higher levels of natural HbCO levels during pregnancy (Linderholm and Lundstrom 1969). Pregnant women's blood has 20-30 percent lower oxygen-carrying capacity due to lower concentration of hemoglobin (Longo 1977). There is some evidence from animal studies and studies of women who smoke that exposure to CO can affect the fetus and may lead to spontaneous abortions, reduced birth weights, and increased perinatal mortality (Windham et al. 1999). Ritz and Yu (1999) have also reported association between CO exposure from ambient air pollution and reduced birth weight. Since women do most of the cooking, which results in greater exposures to CO from cooking smoke, there is a double burden on women (especially among those cooking with biomass fuels), i.e., greater exposures and greater impact of exposures.

There is also evidence to suggest that in early years of life biological and genetic factors are favorable to female children than male children in relation to most infectious diseases (Waldron 1998; Tabutin and Willems 1998). To the extent that this occurs, effects of cooking smoke exposure may be greater in boys than in girls.

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<sup>1</sup> TSP stands for total suspended particulate matter, measured in milligrams per cubic meter.

<sup>2</sup> CO stands for carbon monoxide, measured in parts per million.

<sup>3</sup> PM<sub>10</sub> refers to particulate matter with an aerodynamic diameter of 10 micrometer or less ( $\leq 10 \mu\text{m}$ ).

Men generally smoke more than women (WHO 1997b). Tobacco smoking may aggravate the effects of cooking smoke and vice versa. However, effects of cooking smoke are confounded by the effects of tobacco smoking only to the extent that biomass fuel use is correlated with tobacco smoking. Even though women smoke much less than men, they are found to have lower lung functions than men in many parts of the world (Byerley et al. 1992). The most obvious reason for this is believed to be the differential exposure to cooksmoke (Smith 1996b).

Because women in many developing countries, particularly among rural poor households who rely on traditional fuels for cooking, tend to be more malnourished than men, effects of indoor air pollution are likely to be stronger among women than among men. However, since there is little gender-disaggregated analysis of effects of indoor air pollution on health, it is not clear if greater smoke exposures to women necessarily lead to greater health impacts. In the case of childhood malnutrition, the general assumption and evidence that young girls are discriminated against boys in quality, quantity, and timeliness in feeding, in schooling, in clothing, and in treatment and care when sick is not reflected in the empirical evidence on gender differentials in nutritional status of boys and girls. Despite widespread discrimination against girls, in country after country, girls tend to fare better than boys on various measures of nutritional status—stunting, wasting, and underweight (Sommerfelt and Arnold 1998; Mishra et al. 1999c).

It is generally believed that cumulative exposures over extended periods, as they occur in the case of women cooking with biomass fuels several hours per day over the years, cause greater health damage. Yet, little is known about these cumulative exposures or their health impacts. We do not know if the effects of smoke exposure on health are linear. In other words, we do not know what the shape of the dose-response curve is for specific pollutants and health outcomes and what the thresholds are. It is possible that if the IAP levels are high beyond a critical level then one may not find a sex differential in the effect, even if women are more exposed.

The sources of exposure to air pollutants depend on gender roles. While women do much of the cooking and stay indoors, men may also have substantial exposures to biomass smoke from other sources, such as brick-making, charcoal-making, and sugar-making activities in rural areas, sitting around open fires and household heating during the winter, as well as indoor cooking. Also, because men spend more time outdoors and at work places, they are more exposed to ambient air pollution, secondary tobacco smoke, and employment-related air pollutants than women. Men are also more likely to come in contact with people infected with diseases. It is, however, important to recognize that women are not a homogeneous group and there are considerable class-gender differences in both gender roles and their implications. Moreover, much of women's work goes beyond the household sector and involves agriculture, manufacturing, and services (Cecelski 1995, 2000; Agarwal 1995; Parikh 1995, 1996). Therefore women are exposed not only to a disproportionate share of indoor air pollution but also other employment-related pollutants.

In many developing countries where sons are preferred over daughters and where the status of women is lower, health problems are less likely to be reported for women. This may lead to an impression that the problem is less serious among women than it actually is. This differential under reporting for women is more likely to occur among less educated women and among women living in biomass-fuel-using households. Not only the health problems in women and

girls are less likely to be reported but also reported later when their problems reach more acute status. And, when sick, women and girls are less likely to receive proper medical attention, which may aggravate their condition and lead to more permanent damage or higher mortality. Such discrimination against women and girls is likely to be greater among biomass-fuel-using households than among cleaner-fuel-using households.

Young children are often carried by mothers or kept in the kitchen area during cooking, exposing them to high levels of smoke (Collings et al. 1990; Albalak 1997). In some parts of the world (for example, in Gambia), young girls are more likely to be carried or kept on mother's back or lap during cooking than young boys (Armstrong and Campbell 1991), but in other areas where son preference is strong (for example, in South Asia), boys may be more likely than girls to be carried or kept in the kitchen area where mothers are cooking. In countries like India with strong discrimination against females, such discriminatory practices may actually benefit girls and result in greater smoke exposure to boys.

Effects of cooking smoke interact with gender roles and other sources of air pollution such as tobacco smoking and ambient air pollution, prevalence of various diseases in the population, and overall health and nutritional status of the population. For example, women in rural areas of South Africa have been found to suffer from a form of silicosis, named "Hut Lung", apparently caused by the interaction of cookfire smoke and the dust generated by daily grinding of maize (Grobbelaar and Batsman 1991). Altitude is another factor that is known to increase the effect of CO exposures, found in large quantities in biomass smoke.

Fuel availability, altitude, frequency and magnitude of rainfall, and temperature all play a role in determining how much time people spend cooking, what kinds of fuels people use, how much time is spent indoors, whether people cook indoors or outdoors, how much space heating is required, what kinds of occupations men and women engage in, etc. Knowledge of the history of fuel switching and current mix of fuel use are also important in determining the extent of cumulative exposures. It is also important to know men's and women's activity patterns and cooking habits within households. For example, do women spend all their time in the kitchen area during cooking or go in and out of the area to check on food?

Because women do most of the cooking and spend more time indoors, they are exposed more to the pollutants and are believed to have greater adverse health impacts. Young children who usually stay with their mothers indoors also have elevated exposures (Parikh 1996; Parikh et al. 1999). Yet, there are few studies that differentiate exposure to indoor air pollution by sex and still fewer that examine the effects in two sexes separately. Even though most studies focus on women and their young children, gender issues are mentioned only peripherally. Most studies start with the assumption that women have higher exposures and greater health impacts than men. Men are generally not included in the study of indoor air pollution. Indoor air pollution studies on children often include both boys and girls, but do not study the exposures and effects separately. Moreover, exposure is usually measured using proxy variables such as type of cooking fuel used in the household, which does not allow sex-disaggregation of exposure data.

## **SEX DIFFERENTIALS IN THE EFFECT OF COOKING SMOKE ON ARI**

### *Relationship between cooking smoke and ARI:*

Acute respiratory infections (ARI) remain the single most important cause of morbidity and mortality worldwide, accounting for about 9 percent of the entire global burden of disease (McMichael and Smith, 1999). In developing countries, an estimated 4.1 million children under age 5 die from ARI every year (WHO 1995).

Extended exposure to high levels of biomass smoke, which contains various irritants, cilia toxic fractions, and mucous coagulating agents, can impair the clearing ability of the lungs and render them more susceptible to infection. There is considerable evidence to suggest that smoke from burning biomass for cooking or space heating is a major risk factor for ARI (WHO 1992, 1997a; Smith 1987, 1996a; Campbell et al. 1989). A number of studies in developing countries have reported an association between indoor air pollution and acute respiratory infections in young children. A comprehensive review of effects of cooking smoke on ARI among developing country children can be found in Smith et al. (2000).

A study involving 240 children under age 2 followed weekly for six months in Nepal found a strong relationship between reported number of hours per day the children spent near the cooking stove and incidence of moderate to severe episodes of acute respiratory infection (Pandey et al. 1989). A study of 744 children under 3 years in Zimbabwe found a significant association between the presence of woodsmoke pollution in the house and lower respiratory disease. The study compared 244 children reported with lower respiratory disease at a hospital with 500 children of similar nutritional and socioeconomic background reported to a local Well Baby Clinic (Collings et al. 1990). In a study of 150 infants coming to a hospital in South Africa, Kossove (1982) observed a significantly higher incidence of acute respiratory infections in children living in homes using wood-fires. A study of 500 Gambian children under five years of age observed a significant association between cooking smoke exposure and acute lower respiratory infections in girls carried on their mothers' back while cooking. However, this study failed to show such an effect in boys (Armstrong and Campbell 1991).

Most studies conducted among older school-age/school-going children fail to find a relationship between cooking smoke and respiratory problems. Azizi and Henry (1991) examined the effects of indoor environmental factors on respiratory illness among 7-12 year old 1501 school children in Kuala Lumpur and found no relationship between exposure to kerosene stoves or wood stoves and respiratory illness. Instead they observed a significant relationship between respiratory illness and mosquito coil smoke. Anderson (1979) also did not find any relationship between woodsmoke and respiratory disease in school children. Anderson examined 112 school children (87 exposed to woodsmoke at night from domestic fires and 25 living in houses free from internal pollution) at weekly intervals for 30 weeks in Papua New Guinea. Tuthill (1984) also did not find any association between the use of woodstoves and the risk of respiratory illness in elementary school-age children. Tuthill observes, "Woodburning was not related to fever, sore throat, runny nose, cough, or wheeze. Bronchitis, asthma, and allergies were not associated with woodstove use or with any of the other woodsmoke exposure measures. No control variables

were related to woodburning and also to acute and chronic respiratory illness” (Tuthill 1984:953).

This lack of relationship between cooking smoke and respiratory illness in school-age/school-going children may be due to the fact that school-age/school-going children tend to spend more time outdoors lowering their exposure indoors and that children living in households with lower levels of indoor pollution can get infected from close interaction with other children in the school.

Repeated or severe childhood chest infections can also lead to chronic lung diseases in adulthood (Woolcock et al. 1970; Colley et al. 1973). Pulmonary function abnormalities, asthma, and chronic respiratory infections and diseases in adults and old people have been linked with childhood episodes of acute respiratory infections, including bronchiolitis and viral pneumonia (Colley et al. 1973; Strobe and Stemple 1984).

#### *Cooking smoke and ARI in India:*

In India, as in many other developing countries, ARI is the leading cause of childhood morbidity and mortality (MOHFW 1998). According to India’s 1992-93 National Family Health Survey (NFHS), one in every five children under age 3 suffered from cough, and one in every fifteen suffered from ARI —defined as a cough accompanied by short, rapid breathing—during the two weeks before the survey (IIPS 1995). For India as a whole, this latter proportion translates into approximately 4.6 million ARI cases among children below age 3 during the two-week period. Also, according to the NFHS, boys in India are more likely to suffer from acute respiratory infections than girls.

India has not only high rates of ARI but also a high proportion of households that use some form of biomass as their primary cooking fuel. In the NFHS, about three-quarters of households reported unprocessed biomass as their major source of energy for cooking food. Cooking in India is often done under poorly ventilated conditions using inefficient stoves that produce a great deal of smoke. Such stoves are often no more than a pit, a *chulha* (a U-shaped construction made of mud), or three pieces of brick. To a considerable extent, life revolves around the cooking area, and women, in particular, spend much of their time exposed to cooking smoke. This leads to high levels of cooking smoke exposures to women, young children, and the elderly who typically stay indoors.

In the following, we examine the effects of cooking smoke from burning biomass fuels on the prevalence of acute respiratory infections among young children. Effects of cooking smoke on ARI are estimated using data on 33,875 children under age 3 from India’s 1992-93 National Family Health Survey, after statistically controlling for the effects of several potentially confounding variables. The analysis is limited to children under age 3 because children under 3 years of age are likely to be exposed to higher levels of cooking smoke than older children as very young children mostly stay indoors with their mothers while older children are likely to spend considerable amounts of time outdoors for play or school. Also, the prevalence of ARI morbidity and mortality is much higher among younger children.

### *Data and methods:*

Data are from India's 1992-93 National Family Health Survey (NFHS). The NFHS collected demographic, socioeconomic, and health information from a probability sample of 88,562 households covering a total of 514,827 persons. All parts of the country except Kashmir and Sikkim are represented in the sample, which covers 99 percent of India's population. The sample is a multi-stage cluster sample (1,405 urban and 2,117 rural primary sampling units), with an overall response rate of 96 percent. Details of sample design are found in the basic survey report (IIPS 1995).

The NFHS asked several questions relating to the current health status of household members. In the case of ARI, mothers within the households were asked whether each of their children under four years of age suffered from ARI. Two questions were used to identify ARI cases—whether the child had been ill with a cough at any time in the past two weeks and whether the child, when ill with a cough, breathed with short, rapid breaths. In countries, such as India, where clinical data on acute respiratory infections are usually not available or very weak, this symptomatic definition of ARI provided by the World Health Organization has proved to provide a fairly accurate assessment of ARI situation in the population (Cabaraban 1993:9).

Cooking smoke, measured indirectly by type of cooking fuel, is the primary explanatory variable. The NFHS used a nine-fold classification of cooking fuel—wood, dung, charcoal, coal/coke/lignite, kerosene, electricity, liquefied petroleum gas, biogas, and a residual category of other fuels. The question was, “What type of fuel does your household mainly use for cooking?” which was followed by the above list of fuels. In our analysis, we have grouped these various cooking fuels into two categories—biomass fuels (wood or dung) and cleaner fuels (charcoal, coal/coke/lignite, kerosene, electricity, petroleum gas, or bio-gas). Persons living in households reporting the residual category of other fuels, used by only about 2 percent of the sample, are excluded from the analysis due to the mixed nature of fuels in that category.

The NFHS did not include a separate category for crop residues, which are known to be an important source of fuel for cooking in India (Ravindranath and Hall 1995). Evidently, most households using crop residues as their primary cooking fuel reported using wood, inasmuch as the proportion of households falling in the residual category of other fuels is only 2 percent.

Because the effects of cooking smoke (from biomass fuels relative to cleaner fuels) on ARI 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 are: availability of a separate kitchen in the house, housing type (indicating quality of construction of roof, walls, and floor), indoor crowding (measured by number of persons per room in the household), sex of the child, urban-rural residence, mother's education, religion of household head, caste/tribe of household head, and geographic region. The effects of cooking smoke on ARI were also analyzed by age of the child. With other variables controlled, there was no significant difference between the effects of cooking smoke on ARI in infants (less than age one) and toddlers (age one and two). The rationale for including these variables as controls is discussed below.

Availability of a separate kitchen is included because it controls to some extent for exposure to cooking smoke and also for household economic status. It is important to control for household economic status because it is an indirect indicator of not only nutrition and health but also access to medical services that might prevent or cure infection. The NFHS did not collect income data, so we have no direct measure of household income. Housing type is included because it is also correlated with household economic status and may also control to some extent for ventilation in the house. Housing type is dichotomized into *kachcha* (made from mud, thatch, or other low-quality construction materials throughout) and *pucca* or semi-*pucca* (made from at least some high-quality construction materials such as bricks, tiles, cement, or concrete). Average number of persons per room in the household controls for indoor crowding, which may also be correlated with exposure to cooking smoke as well as household economic status, unhygienic conditions, and exposure to infection.

Sex of child is included mainly because girls and boys may have differential exposure to cooking smoke. Urban-rural residence is included because it is correlated with type of cooking fuel, household economic status, and access to and use of medical services which may prevent or cure infection. Education is included because it is also correlated with access to and use of medical services, as well as cooking fuel type and economic status. Religion and caste/tribe are included because they may capture cultural and life style differences that are correlated with type of cooking fuel, cooking practices, and intensity of exposure to cooking smoke. Geographic region is included to control for regional differences in climate, topography, and local customs that may be correlated with both infection and exposure to cooking smoke.

In the correlation matrix of predictor variables, all pairwise Pearson correlation coefficients are under 0.5, except for the correlation between fuel type and urban residence, which is 0.58. These values are low enough that multicollinearity is not a problem in the multivariate analysis that follows. In any case, the analysis was also done separately for urban and rural areas and effects of cooking smoke did not differ much by residence (analysis not shown here).

Because the NFHS did not ask about tobacco smoking, it is not possible to control for tobacco smoking by household members. If, however, tobacco smoking is as common among persons living in households using biomass fuels as among persons living in households using cleaner fuels, the estimated effects of cooking smoke from biomass fuels should not be biased by the lack of a control for tobacco smoking. It may be noted that a very small proportion of women in India smoke tobacco (WHO 1997b). Results are presented later for boys and girls separately as well as together.

Initially we grouped fuels into three categories -- high-pollution fuels (wood and dung), medium-pollution fuels (charcoal, coal/coke/lignite, and kerosene), and low-pollution fuels (electricity, petroleum gas, and bio-gas). However, differences between medium-pollution fuels and low-pollution fuels in their effects turned out not to be statistically significant, so we regrouped fuels into just two categories -- biomass fuels (wood and dung) and cleaner fuels (charcoal, coal/coke/lignite, kerosene, electricity, petroleum gas, and bio-gas). Households using "other fuels" are excluded from the analysis.

It should be noted that coal/coke/lignite can also be highly polluting, but we classify them here as cleaner fuels in terms of exposure to cooking smoke. We do this because most smoke from these fuels is produced within the first few minutes after the fire is started. Moreover, in India, these fuels are usually burned on portable stoves that are often started in open areas and then, when the fire is burning cleaner, brought indoors for cooking. Biomass fuels, on the other hand, are usually burned on non-portable stoves and require regular fuel-feeding, resulting in continuous release of considerable amounts of smoke. Coal/coke/lignite account for 4 percent of cooking fuel use in our sample. A separate analysis of effects of biomass fuels with and without coal/coke/lignite did not alter the effects of biomass fuels significantly (results not shown).

In our analysis, type of cooking fuel is represented by a dummy variable with value 1 for biomass fuels and 0 for cleaner fuels. This is our principal predictor variable.

Because our response variable—prevalence of ARI—is dichotomous, we use logistic regression to estimate the effects of cooking fuel type on ARI with the nine demographic and socioeconomic variables mentioned above as controls. Results are presented mostly in the form of odds ratios with 95% confidence intervals. The estimation of confidence intervals and significance levels 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 1997).

In the NFHS, certain states and certain categories of households were over sampled. In all our analysis, weights are used to restore the representativeness of the sample (IIPS 1995).

### *Results:*

In this section we present the effects of biomass fuel use on the prevalence of acute respiratory infections among children using multivariate analysis methods discussed earlier. We first present the effects of biomass fuel use and the control variables on ARI, and then examine gender differentials in these effects.

Figure 2 shows unadjusted and adjusted effects of cooking smoke (from biomass fuels relative to cleaner fuels) on ARI rates, with ARI rates measured as ARI cases during the two weeks before the survey per 1,000 children. The unadjusted and adjusted prevalence rates shown in this figure are predicted values derived by logistic regression and multiple classification analysis, which is a method for transforming regression results into simple bivariate tables which can be depicted as bar graphs (Retherford and Choe 1993). The unadjusted prevalence rates are predicted from a logistic regression of ARI (1 if suffered from ARI in the two weeks preceding the survey, 0 otherwise) on type of cooking fuel (1 if wood or dung, 0 otherwise). The adjusted prevalence rates are predicted from a logistic regression of ARI on type of cooking fuel and the nine control variables discussed earlier. In the calculation of adjusted prevalence rates, the control variables are held constant by setting them to their mean values in the underlying logistic regression. In the calculation of both unadjusted and adjusted prevalence rates, the value of the constant term in each underlying logistic regression is reset so that, with the predictor variable or variables set to

their mean values, the prevalence rate predicted by the regression equals the observed prevalence rate.

Figure 2 shows that the unadjusted ARI rate is substantially higher among children living in households using biomass fuels than among those living in households using cleaner cooking fuels (an ARI rate of 72 compared with 49 per 1,000). Adjusting for the control variables reduces this difference, but not by much (to 69 compared with 53 per 1,000). The adjusted ARI rate is still one-third higher among children living in households using biomass fuels than among children living in households using cleaner fuels.

<Figure 2 about here>

The unadjusted and adjusted effects of the control variables on ARI among young children are also of interest and are summarized in Table 3, along with the effects of cooking smoke (from biomass fuels relative to cleaner fuels) already portrayed graphically in Figure 2. Note that, in the adjusted column of Table 3, the control variables change as one moves down the column. For any given predictor variable specified by a row label, the set of control variables consists of the remaining predictor variables in the table.

In Table 3, availability of a separate kitchen and indoor crowding have virtually no effect on the ARI rate. House type has a more substantial effect, the ARI rate being much lower for children living in *pucca* and semi-*pucca* houses than for those living in *kachcha* houses. Among these three variables house type dominates, perhaps because house type is more highly correlated with economic status, which reflects nutritional levels, access to medical services, and overall health.

<Table 3 about here>

There is some evidence to suggest that girls are biologically stronger than boys. If that is the case, one should expect a somewhat higher prevalence of ARI in boys than in girls. This is indeed what we find. The unadjusted prevalence of ARI in girls is about 20 percent less than that in boys (Figure 3). However, there is also ample evidence of discrimination against girls in food (breastfeeding in particular), clothing, treatment, and care. This discrimination, to the extent that it occurs, should compensate for any biological disadvantages that boys might have in getting ARI, and one should expect the prevalence of ARI in girls to be at least as high as in boys, if not higher. A substantially lower prevalence of ARI in girls points toward the possibility of differential under reporting of ARI by mothers in the case of girls. This would be consistent with previously published findings from the NFHS that boys with ARI are more likely than girls to be taken to a health facility or provider for treatment (IIPS 1995). Both these results suggest that ARI is taken more seriously when it is a boy who is sick. This sex differential in ARI rate remains virtually unchanged even when various socioeconomic factors are controlled statistically, indicating that a lower ARI rate among girls is not due to variations in these socioeconomic factors. We shall look at the sex differentials in the effects of cooking smoke on ARI later.

<Figure 3 about here>

The unadjusted ARI rate is considerably lower in urban areas than in rural areas, but the difference is not statistically significant when the other socioeconomic factors are controlled statistically. Children whose mothers are literate but did not complete high school have a substantially higher ARI rate than children whose mothers completed high school or children whose mothers are illiterate. This last finding is unexpected. A possible explanation is that illiterate mothers may be less likely than more-educated mothers to report incidents of ARI among their children. By religion, children belonging to “other” religions have a lower ARI rate than either Hindu or Muslim children, but the adjusted differences are not statistically significant, perhaps mainly because the number of children in the “other” religion category is small. Caste/tribe has no effect on the ARI rate. The ARI rate is much higher in the north and northeast than in other regions, perhaps because of the colder climate.

If mothers who use biomass fuels for cooking are less likely to report ARI than mothers who use cleaner fuels, then the effect of cooking smoke on the prevalence of ARI is likely to be underestimated. If, at the same time, ARI is more likely to be reported for boys than for girls, then this underestimation will be less for boys. As a result, the effect of cooking smoke on the prevalence of ARI will appear to be larger for boys than for girls. To test this hypothesis, the data were analyzed separately for boys and girls, with sex of child deleted from the set of control variables. Results are shown in Figure 4 and Table 4 (only adjusted effects are presented).

<Figure 4 about here>

Figure 4 shows that not only is the prevalence of ARI higher for boys than for girls, but also the effect of biomass fuels on the ARI rate is considerably larger for boys than for girls, as hypothesized. The adjusted prevalence of ARI is higher among boys than among girls in both biomass-fuel-using and cleaner-fuel-using households. The effect of cooking smoke (from biomass fuels relative to cleaner fuels) is about twice as high among boys as among girls.

Differential underreporting of ARI by sex may not be the only factor responsible for higher ARI rate and a larger effect of cooking smoke for boys than for girls. Another reason may be that mothers in India are more likely to carry young boys than girls with them or keep them in the kitchen area while they are cooking. To the extent that this occurs, boys would have greater exposure to cooking smoke than girls, which could result in both a higher level of ARI and a larger effect of cooking smoke in boys.

Effects of the control variables on the prevalence of ARI separately for boys and girls, as measured by odds ratio, are shown in Table 4. The effects of control variables are rather similar among boys and girls and similar to those discussed earlier in Table 3 for both sexes combined.

<Table 4 about here>

*ARI attributable to cooking smoke:*

It is useful to consider what proportion of ARI prevalence may be due to smoke from biomass fuels. One can calculate a ‘population attributable prevalence proportion’ as

$$\frac{\text{Prevalence in total population} - \text{Prevalence in unexposed group}}{\text{Prevalence in total population}}$$

This measure, which reflects the proportion of households that use biomass fuels as well as the effect of cooking smoke from biomass fuels on ARI, can be interpreted as the proportionate reduction in ARI that would occur if everyone had been using cleaner fuels all along. It indicates (after controlling for other demographic and socioeconomic variables by holding them constant) that the prevalence of ARI among children under age 3 would be 20 percent lower if everyone had been using cleaner fuels.

## DISCUSSION

A review of evidence on gender aspects of indoor air pollution and health reveals that differences in gender roles result in differential exposures to indoor air pollution among males and females. Moreover, gender differentials in nutritional status, treatment, and care result in differential effects of these exposures on health. Also, there are biological differences between males and females that mediate the effects of indoor air pollution on health. Yet, there are very few studies that address gender aspects of indoor air pollution and its health impacts, and still fewer that empirically examine these gender differentials. Most studies assume that women have greater exposure than men, and do not include men or even discuss how sex and gender roles determine differential exposure levels and impacts.

Results from the analysis of data from India's National Family Health Survey indicate that prevalence of ARI is much greater among boys than among girls, and that exposure to cooking smoke (from biomass fuels compared with cleaner fuels) substantially increases the risk of acute respiratory infections among children under 3 years of age. This is true even when the effects of a number of potentially confounding variables are statistically controlled by holding them constant. The adjusted effect of cooking fuel type on the prevalence of ARI is large (OR=1.32) and statistically significant ( $p<.01$ ). The adjusted effects of cooking smoke are also large when the analysis is done separately for boys and girls, but the effect is considerably greater for boys (OR=1.41) than for girls (OR=1.21).

There is some evidence to suggest that young girls are biologically stronger than boys, but there is considerable evidence of discrimination against girls in feeding, treatment, and care. The discrimination against girls, to the extent that it occurs, should compensate for any biological disadvantages that boys might have in getting ARI, and one should expect the prevalence of ARI in girls to be at least as high as in boys, if not higher. A substantially lower prevalence of ARI in girls points toward the possibility of differential underreporting of ARI by mothers in the case of girls.

The effect of cooking smoke on ARI is large and statistically significant for both boys and girls, and the effect is considerably larger for boys than for girls. This may in part be due to greater

underreporting of ARI for girls and greater underreporting in biomass-fuel-using households than in cleaner-fuel-using households. Higher ARI rate and greater effect of cooking smoke among boys may also be due to the fact that mothers in India are more likely to carry young boys than girls or keep them in the kitchen area while cooking.

Our findings on gender differentials in the effect of cooking smoke on ARI are opposite to the findings from the Gambian study, which found a significant association between cooking smoke and ARI in girls, but not in boys (Armstrong and Campbell 1991). However, given that in the Gambian case girls were more likely to be carried on their mothers' back (Armstrong and Campbell 1991) and in India boys are more likely to be carried or kept around kitchen area, the results from the two studies are not necessarily inconsistent.

The true effects of cooking smoke on ARI may be stronger than we have estimated, for the following reasons. The first reason is that households in India typically use a combination of cooking fuels, whereas we have information only on the primary cooking fuel. Our estimated effects are attenuated to the extent that a mix of biomass fuels and cleaner fuels is actually used by many households instead of biomass fuels alone. Our estimated effects would also be larger had we measured the effects of biomass fuels relative to a very clean fuel such as electricity instead of a residual category of other fuels that includes charcoal, coal/coke/lignite, kerosene, petroleum gas, and bio-gas as well as electricity.

Another reason why our estimates of effect of cooking smoke on ARI may be underestimated could be due to the fact that there is some selection in the sample due to ARI related mortality. To the extent that children living in poorer biomass-fuel-using households are more likely to die from ARI, our estimates of effect of cooking smoke on ARI are downwardly biased. Finally, there is also a possibility of underreporting of ARI due to lack of awareness that the child had the disease during the two-week reference period. Underreporting due to lack awareness may be greater among persons living in households using biomass fuels, as well as among girls because of their low status relative to boys. This differential underreporting by sex, to the extent that it occurs, would contribute to underestimation of the effect of cooking smoke on the prevalence of ARI and to underestimation of the gender differential in the effect of cooking smoke on the prevalence of ARI.

There are several factors that could affect the validity of our conclusions. Fuel type is not an ideal measure of exposure to smoke. And our data do not allow disaggregating exposure to cooking smoke by gender because we use main type of cooking fuel used in the household as a proxy for exposure to cooking smoke. Moreover, reports of ARI symptoms by mothers are not as accurate as clinical measures of the disease. Also, we were not able to control directly for extent of use of medical services, because the NFHS did not collect any information on this subject; however, our set of control variables includes several measures of socioeconomic status, which are correlated with access to and use of medical services. The NFHS also did not collect any data on such behaviors as tobacco smoking in the household, which might account for some of the variation in prevalence of ARI among young children.

The socioeconomic variables included as controls in our models are likely to capture much, but not all, of the effects of these missing variables on ARI. Because the NFHS did not ask about

tobacco smoking, it is not possible to control for tobacco smoking by household members. If, however, tobacco smoking is as common among persons living in households using biomass fuels as among persons living in households using cleaner fuels, the estimated effects of cooking smoke from biomass fuels should not be biased by the lack of a control for passive smoking. In other words, tobacco smoking by parents or other household members is a confounding factor only to the extent it is correlated with cooking fuel type. Future health surveys should nonetheless consider including additional questions on these variables.

Case-control studies using epidemiological methods and clinical measures of ARI would be especially useful for untangling the effects of the various risk factors, although cross-sectional surveys such as the NFHS are also very useful because they typically cover much larger and more representative populations at a considerably lower cost per respondent. Further research based on better measures of smoke exposure and clinical measures of ARI is needed to further substantiate our findings. Such research is important in view that ARI is the single largest killer of children in India and in the world.

In such efforts, there is need to collect sex-disaggregated data on smoke exposure and health outcomes. Information on men's and women's activity patterns, cooking habits, and time spent in various microenvironments, and information on gender differentials in access to and utilization of health care services is needed to better understand how sex and gender roles mediate the effects of indoor air pollution on health. There is also need to determine exposure-response relationships and threshold levels for effects of specific pollutants on health outcomes separately for males and females. Detailed data on fuel-mix, fuel-switching, and cumulative exposures should be collected.

There is need for a holistic approach in addressing gender issues in indoor air pollution and its impact on health. An integrated approach that includes both sexes, not just females or males, is called for. In designing and implementing policies and intervention programs, such as the improved cookstove program, special attention should be given to the local community needs and the needs of women, who do most of the cooking. Communities should be educated about adverse health effects of indoor air pollution and about differential exposures and health impact among males and females.

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