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Wood-burning stoves and lower respiratory illnesses in Navajo children

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Outline

Abstract

Background: Acute lower respiratory illnesses (ALRI) have been associated with exposure to domestic smoke. To examine further this association, a case-control study was conducted among Navajo children seen at the Public Health Service Indian Hospital at Fort Defiance, AZ.

: Cases, children hospitalized with an ALRI (n = 45), were ascertained from the inpatient logs during October, 1992, through March, 1993. Controls, children who had a health record at the same hospital and had never been hospitalized for ALRI, were matched 1:1 to cases on date of birth and gender. Home interviews of parents of subjects during March and April, 1993, elicited information on heating and cooking fuels and other household characteristics. Indoor air samples were collected for determination of time-weighted average concentrations of respirable particles (i.e.

: Age of cases at the time of admission ranged from 1 to 24 months (median, 7 months); 60% of the cases were male. Matched pair analysis revealed an increased risk of ALRI for children living in households that cooked with any wood (odds ratio (OR), 5.0; 95% confidence interval (CI), 0.6 to 42.8), had indoor air concentrations of respirable particles >=65 [mu]g/m3 (i.e. 90th percentile) (OR 7.0, 95% CI 0.9 to 56.9), and where the primary caretaker was other than the mother (OR 9, 95% CI 1.1 to 71.4). Individual adjustment for potential confounders resulted in minor change (i.e. P

Conclusions: Cooking with wood-burning stoves was associated with higher indoor air concentrations of respirable particles and with an increased risk of ALRI in Navajo children.

INTRODUCTION

Acute lower respiratory infections (ALRI) are a leading cause of morbidity and mortality in children in many parts of the world, 1-4 including Native American communities. 5 Mortality rates from pneumonia are 6 times higher in Native American children than in Anglo-American children of the same age.5 Epidemiologic studies conducted in developing and developed countries 6-14 have reported an association between ALRI in young children and exposure to domestic smoke from biofuels. The latter is a mixture of gases and particles, including respirable particles (i.e.

In 1990 Morris et al.17 reported that Navajo children living in houses with wood-burning stoves for heating were at increased risk of ALRI compared with children living in houses with other types of heating sources. This observation was not a result of confounding by passive smoking, indicators of socioeconomic status, family history of asthma or recent exposure to infection and suggested exposure to wood smoke as a risk factor for ALRI. However, there were no measurements of combustion emissions to indicate that wood smoke was the exposure involved. Confounding by access to a health care facility was not excluded as a possible explanation. If users of wood-burning stoves live far from and have less access to a health care facility, then progression of respiratory illnesses to a severe state requiring hospitalization might occur more frequently among users of wood stoves. This situation could give rise to a higher rate of severe ALRI among users of wood stoves when compared to nonusers. In the Navajo Reservation where health care is available to all Navajos at no cost, one determinant of timely use of health services and possibly of severity of ALRI may be the distance to the nearest hospital or clinic. Thus when comparing users and nonusers of wood-burning stoves with respect to the risk of hospitalization with an ALRI, it may be important to account for distance from the nearest clinic or hospital.

The Navajo Reservation, located at an elevation of 4000 to 11 000 feet in parts of Utah, Arizona and New Mexico, has a desert climate, with seasonal extremes of temperatures ranging from -20 to 100[degrees]F. More than 200 000 Navajo people live on this reservation, many in remote rural settings. Although one-room dwellings built from logs and clay ("hogans") were common in the past, today the more common type of dwelling is a small one- to two-room wooden frame house. This type of dwelling is usually part of a cluster of homes with two to four other small

frame homes. Nowadays many Navajo homes have gas or electricity; however, biofuels such as wood and coal continue to be used for heating and cooking 17 so that the potential for exposure to domestic smoke still remains.

We conducted a case-control study of ALRI among Navajo children to evaluate the relationship between ALRI and cooking and heating fuels. As part of this evaluation we obtained measurements of indoor air-borne concentrations of respirable particles and examined the variation in concentration of such particles in relation to fuels used and to the case-control status of study subjects. We also took into account distance from the residence of subjects to the clinic.

METHODS

Study population. The study population included Navajo children registered at the Fort Defiance Hospital and Indian Health Service Facility that provides inpatient, ambulatory and emergency services to Navajos in Fort Defiance, AZ, a population of approximately 19 400 in eastern Arizona. The study protocol was approved by the necessary Indian Health Service committees and the Institutional Review Board of The Johns Hopkins University School of Hygiene and Public Health.

Cases were children between 1 and 24 months of age hospitalized with a primary diagnosis of ALRI (lower respiratory illness, bronchiolitis or pneumonia) during the period October 1, 1992, to April 1, 1993. Cases were ascertained from the hospital's pediatric inpatient logs.

Potential controls were children who had sought care at the Fort Defiance Indian Health Service Hospital at least one time since birth during the same time period as the cases but for conditions other than ALRI. A list of potential controls was obtained from the hospital computerized files that did not distinguish between inpatient and outpatient records. Children with cardio/respiratory anomalies, admission to the hospital during the first month of life for respiratory illness or previous hospitalization for ALRI as determined by chart review or interviews of parents were excluded. For each case one control matched for gender and age (within 30 days of the case) was selected. Since hospitalization for other than ALRI was infrequent, inpatient status was not used as a matching criterion.

Interviews. Parents of cases and controls were interviewed at home during the months of April and May, 1993, by trained interviewers using a standardized questionnaire. Information was obtained on availability of electricity and running water in the home, type of home (i.e. cement/brick, other), relationship of primary caretaker to the study child (i.e. mother, father, grandmother, aunt, other), distance of the clinic/hospital from the home, whether transportation to the clinic was a problem, presence of tobacco smokers in the household, occasional smoking of ceremonial herbs in the home, number of rooms in the home, number of children living in the home and type of cooking and heating fuels.

Measurement of respirable particles. Indoor concentration of respirable particles (i.e. Respirable particulate matter was measured in the study homes during April and May, 1993, 2 weeks to several months after the hospital admission for the case child. Air sampling in the paired control households followed sampling in the case households by 0 to 28 days (median, 5 days; interquartile range, 0 to 8 days). Average low outdoor temperatures during air sampling were 19.3[degrees]F for the cases and 19.7[degrees]F for controls, indicating similar levels of potential heat use.

Filters were analyzed gravimetrically to determine the mass of respirable aerosol collected. The time-weighted-average concentration of respirable particles was calculated during the sampling period and expressed as micrograms of respirable particles per m3 of air. Laboratory analyses were conducted without knowledge of the case-control status of the households in which the filters were collected.

Statistical analysis. Frequency distributions were obtained for various demographic and exposure characteristics by case-control status of study children. Fuels used for heating and cooking were compared for case and control households. Unadjusted matched odds ratios (OR) and 95% confidence intervals (CI) for ALRI and various characteristics were obtained from conditional maximum likelihood estimates.19 Distributions of time-weighted-average concentrations of respirable particles for cases and controls were graphically compared, and a conditional logistic regression model was used to examine the risk of ALRI in relation to the concentration of respirable particles; cubic splines and dummy variables were used to reflect the relationships accurately.20 Possible confounding of observed associations between ALRI and characteristics by socioeconomic indicators (i.e. running water, type of home, number of rooms, number of children living in the home and distance from clinic/hospital), occasional smoking of ceremonial herbs and the presence of a smoker in the household were evaluated with conditional logistic regression to retain the matched design in the analysis. Adjusted ORs and CIs were obtained from the regression parameters.19 The relationship of the concentration of respirable particles (untransformed and log-transformed) to indoor sources of combustion emissions (i.e. heating with wood vs. gas/electricity, cooking with wood vs. gas/electricity, the presence of a smoker in the home and ever smoking of traditional herbs in the home) was examined with analysis of variance. Statistical analysis was performed with SAS and EGRET.20, 21

RESULTS

Forty-five matched case-control pairs were enrolled in the study (Table 1). The age range for case children at the time of hospital admission was 1 to 24 months (median, 7 months). Controls were within 30 days of age of the cases (median, 7 months). Twenty-seven of 45 case-control pairs were male. Compared with control households case households were less likely to have electricity, more than two rooms and the mother as the primary caretaker. Also cases tended to live farther from the clinic and to have slightly more frequent problems with transportation. On the other hand case households were less likely to have cigarette smokers or to smoke traditional herbs in the home. In all study households the most common heating fuel was wood; the prevalence of heating with wood was slightly greater in case than in control households. Other common heating fuels include bottled propane gas, electricity and coal; kerosene was rarely used. The most common cooking fuels were bottled propane gas, electricity and wood; coal was rarely used. As with heating, cooking with wood was more prevalent in case than in control households.

Various patterns of use of heating and cooking fuels were evident (Table 2). The most common heating fuel patterns were: gas or electricity (i.e. gas/electricity) alone; wood alone; and the combination of wood plus coal. A case excess was suggested for heating fuel patterns that included wood. On the other hand the most common cooking fuel patterns were: gas/electricity alone; and wood alone. Also a case excess was apparent for cooking patterns that included wood. Coal was never used alone for heating or cooking. The 16 households where cooking fuel was reported as "none" indicated having used a butane gas stove for cooking.

With study houses that used gas/electricity alone as a reference, we compared discordant case-control pairs on exposure with (gas/electricity plus any other fuels), any wood, and any coal (Table 3). There was a 5-fold excess risk of ALRI among children living in houses that used any wood for cooking; however, the 95% CI for this association was wide because of small numbers. The magnitude of the association with cooking with wood changed little (i.e.

Also there was an association between ALRI and the primary caretaker. Compared with controls, cases were 9 times more likely to have someone other than their mother as the primary caretaker. There were no statistically significant associations between ALRI and any other variables examined.

Analysis of air samples collected from study houses (n = 90) showed that the time-weighted average concentration of respirable particles ranged between 3.2 and 186.5 [mu]g/m3 (median, 22.4 [mu]g/m3; geometric mean (GM), 20.9 [mu]g/m3). Grouping of houses by patterns of fuels used revealed that houses that used gas/electricity alone for heating and cooking (n = 33) had the lowest concentrationof respirable particles (median 22.2 [mu]g/m3; GM

18.8 [mu]g/m3), whereas houses that cooked with gas/electricity but heated with wood alone (n = 3) had higher levels of particles (median, 100.9 [mu]g/m3; GM 57.4 [mu]g/m3). Also houses that cooked and heated with wood alone (n = 4) had some of the highest concentrations of respirable particles (median, 85.6 [mu]g/m3; GM 62.8 [mu]g/m3). There was no appreciable variation in the concentration of respirable particles with any other source of respirable particles (i.e. smoker in the house, smoking of traditional herbs in the home, type of home). Further, in analysis of the variation in concentration of respirable particles with heating and cooking fuels and other possible sources of emissions, the only variables that explained some of the variance in the log concentration of respirable particles (R2 = 0.098) were heating with wood alone (P = 0.059) and heating and cooking with wood alone (P = 0.017).

The concentration of respirable particles ranged from 3.2 to 186.5 [mu]g/m3 (median, 24 [mu]g/m3; interquartile range, 12 to 42.1) in case houses and from 4 to 71 [mu]g/m3 (median, 22 [mu]g/m3; interquartile range, 13 to 33.5) in control houses (Fig. 1). At the lower end of the concentrations of respirable particles, there were similar numbers of cases and controls; however, at the higher end of the concentrations cases predominated. A cubic spline was used to relate the concentration of respirable particles to case status in a conditional logistic regression model. Based on the results of this cubic spline, concentrations of respirable particles were categorized into 3 and >= 5 [mu]g/m3 (i.e. 90th percentile). The risk of ALRI among children living in houses with a respirable particle concentration >=65 [mu]g/m3 relative to those living in houses with a respirable particle concentration 3 was increased 7-fold (OR 7.0, 95% CI 0.9 to 56.9). The magnitude of this association changed little (i.e.

DISCUSSION

In this hospital-based case-control study, the risk of hospitalization with an ALRI among Navajo children was 5-fold for children living in houses that cooked with wood as compared with the risk for children living in houses that cooked with gas or electricity alone. Further, children living in houses with concentrations of respirable suspended particles >=65 [mu]g/m3 (i.e. 90th percentile of the concentration of respirable particles in study houses) experienced a 7-fold excess risk of ALRI (OR 7.0, 95% CI 0.9 to 6.9) as compared with children living in houses with lower concentrations of respirable particles. These findings did not change with adjustment for potential confounders measured, including distance from the clinic. The risk of ALRI among Navajo children was not associated with the less prevalent use of coal for either heating or cooking or with other possible sources of combustion emissions such as kerosene, smokers in the home, and smoking of traditional herbs. Houses that used wood alone for either heating or cooking had higher indoor airborne concentrations of respirable particles than houses that did not use any biomass fuels. In addition the risk of hospitalization with ALRI among Navajo children was found to be associated with the child's primary caretaker. None of the other variables examined was associated with the risk of ALRI. Since cases and controls were matched for age and gender, the role of these variables in the risk of ALRI could not be evaluated.

Our finding regarding ALRI in Navajo children and wood-burning stoves confirm earlier observations by Morris et al.17 and suggest that this association is likely to reflect effects from exposure to domestic smoke rather than confounding by distance from a health care facility. This finding also is consistent with reports of lower respiratory illnesses in young children exposed to high concentrations of domestic smoke in poorly ventilated dwellings in developing countries. 6-12 Studies of health effects in younger children exposed at the lower levels of respirable particles generally observed in more developed countries are few and have not indicated a consistent excess risk of respiratory effects.13, 14, 22 The indoor air concentration of respirable particles in the houses in our study varied between 3 and 186 [mu]g/m3 (median, 22 [mu]g/m3), which falls within the range observed in studies in developed countries. An appreciable increase in risk of ALRI was evident only at levels >=65 [mu]g/m3, observed in only 10% of the study houses. Nevertheless because we conducted the air samplings of study houses in the late spring, and after the onset of illness of the cases, it is possible that our measurements underestimated the levels of domestic smoke from wood-burning stoves to which study children may have been exposed.

Two types of wood-burning stoves were used in the study houses. One type was box-shaped and had side doors and a vent to the outside. Another type was cylindrical and consisted of a half metal drum with an opening on the side and a vent to the outside. The side opening in the latter stove allowed the addition of fuel to the stove as well as the emission of smoke inside the house. The types of wood used as biofuel in the Navajo Reservation, in decreasing order of frequency, were: pine; cedar; juniper or pinion; and oak.

Smoke from biomass fuels is a complex mixture of particles and gases. Although the composition and concentrations of specific contaminants in smoke may vary by the source of combustion, an association between ALRI and smoke from various sources, including biomass fuels, has been documented in a number of epidemiologic studies. 6-15, 23, 24 Ninety to 95% of the total particulate mass in wood smoke may be found in particles

The results of this study are particularly noteworthy in light of the inherent limitations that favor the null hypothesis. One potential limitation is the small expected statistical power caused by a small sample size, which led to some imprecision in the relative risk estimates. Another related limitation is that we did not evaluate specific respiratory illnesses because of the small sample size; inclusion of some conditions not associated with exposure probably diluted any real effect. Nondifferential misclassification of exposure status also contributed to bias toward the null. Factors contributing to such misclassification include the limited measurements of products of fuel combustion, obtaining environmental measurements after the onset of disease and conduct of the study at a time (late spring) when there may have been less of a case-control differential in the burning of wood for heating given the warmer climate than in the earlier winter months.

Masking the interviewers with respect to case-control status of subjects was not possible as interview elicited a medical history. We attempted to control for interviewer bias by: (1) administering written rather than verbal questionnaires unless reading assistance was required; (2) using predominantly close-ended questions; and (3) instructing the interviewer to leave the air filters in the study homes regardless of the air temperature, household cooking or evening travel plans. Masking the respondents was not possible because they had to be informed of the nature of the study. Thus there was a potential for differential recall or reporting on the use of wood stoves. However, the actual measurements of indoor air concentrations of respirable particles were not subject to such biases and further indicate that the main source of the higher levels of particles was cooking with wood.

Although adjustment for the potential confounders that we measured had little material effect on the magnitude of the association of ALRI with measures of indoor air pollution, we cannot exclude the possibility of uncontrolled confounding by variables that we did not measure such as prematurity and family history of reactive airway disease. Exclusion of children with any cardio/respiratory anomalies and children hospitalized during the first month of life from the study population would tend to decrease the possibility of confounding by severe prematurity. However, confounding by differences in birth weight or family history of asthma cannot be excluded.

Chance is an unlikely explanation for our findings. The consistency of the association of ALRI with wood-burning stoves and with high concentrations of respirable particles suggests that the association is real rather than coincidental.

An unexpected secondary finding in this study was that children hospitalized with ALRI were more likely to have someone other than their mother as their primary caretaker. This observation warrants corroboration because it may have important implications for resource allocation and the impact of such an allocation on the health of children.

Our observations highlight the importance of considering indoor air pollution as a possible risk factor for severe ALRI among some groups of Native American children. Further studies are needed to elucidate the relationship between

heating and cooking with biofuels and ALRI in young Navajo children. Such studies should also assess the relationship of stove quality, ventilation and other products of combustion including oxides of nitrogen and sulfur to duration and severity of health effects. Also further work is warranted to implement and evaluate inexpensive prevention interventions, such as education of caretakers and simple improvements in home heating and ventilation systems.

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