# Wood-Burning Stoves and Lower Respiratory Tract Infection in American Indian Children

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**• Some studies suggest that home use of wood-burning stoves is an independent risk factor for lower respiratory tract infection in young children. To test this hypothesis in a population with a high prevalence of wood-burning stove use, we studied Navajo children with diagnosed pneumonia or bronchiolitis. We matched each case (≤24 months of age) with a child of identical sex and age who was seen for well-child care or a minor health problem, and we interviewed an adult caretaker about family history and environmental exposures. Analyzing 58 case-control pairs, we found that home wood-burning stove use, recent respiratory illness exposure, family history of asthma, dirt floors, and lack of running water in the home increased the risk of lower respiratory tract infection. On multiple logistic regression analysis, however, only wood-burning stove use and respiratory illness exposure were independently associated with higher risk.**

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Lower respiratory tract infections (LRTIs) are a major cause of morbidity and mortality in young children. The incidence of all LRTIs approaches 20% to 25% for the first 2 years of life and decreases steadily with age.[1] In Great Britain, 5% to 10% of infant deaths are due to LRTI, mostly acute bronchiolitis and pneumonia.[2] Bronchiolitis alone accounts for 11% of LRTI cases during the first year of life, decreasing to 6% by age 2 years.[3] Although the case fatality rate of bronchiolitis is less than 1%,[4] bronchiolitis and viral pneumonia at an early age are associated with later pulmonary function abnormalities, additional LRTIs, asthma, and other respiratory symptoms.[5-9] These findings suggest a link between childhood LRTI and chronic lung disease and emphasize the importance of prevention of bronchiolitis and viral pneumonia.

Several inherited and environmental factors are associated with increased risk of LRTI. A family history of asthma,[9-11] respiratory allergy,[9] and chronic cough[12] are possible genetic risks. Prematurity and mechanical ventilation increase the infantile bronchiolitis rate.[13] Congenital or structural abnormalities also increase the incidence of LRTI.[5] Numerous environmental factors have been implicated. Parental smoking, especially during the first year of life, is a consistently demonstrated risk factor.[10-12,14-17] Other, less-well-established risks are gas stove use,[16,18] crowded living conditions,[10,11,19] high number of siblings,[10] school-age siblings,[10,11] low socioeconomic status,[19,20] air pollution,[21] non–breast-feeding,[22] and wood-burning stove (WBS) exposure.[23,24]

An unpublished preliminary study done at the Indian Health Service Tuba City (Ariz) Hospital in 1987 showed a possible relationship between WBS exposure and an increased incidence of bronchiolitis and pneumonia. The Navajo and Hopi people living on their northeast Arizona reservations are unusual in the United States because many live in traditional housing without electricity, gas, or running water and use a WBS as the sole source of heat. The prevalence of cigarette smoking is also low on the reservation, decreasing the influence of one of the strongly associated risks for LRTI. In this matched case-control study we tested the hypothesis that home use of a WBS is associated with an increased risk of LRTI in young children.

## SUBJECTS AND METHODS

### Selection of Patients

The US Public Health Service Hospital at Tuba City is the principal source of both inpatient and outpatient medical care for about 20 000 Navajo and Hopi people who live in the Tuba City service unit (about 4000 square miles) on the Navajo Reservation. The hospital also provides inpatient care for an additional 15 000 Navajo who live in the adjacent Kayenta service unit, which has its own ambulatory health center. The closest sources of private or non–Public Health Service health care are over 70 miles from Tuba City in Flagstaff or Page, Ariz.

Children 24 months of age or younger who presented to the Tuba City Hospital outpatient clinic or emergency department were identified as cases, controls, or exclusions. Case children were those with a diagnosis of bronchiolitis or pneumonia. To be included, a case of pneumonia required the following: (1) fever and respiratory distress as evidenced by retractions, grunting, flaring, or paroxysmal breathing; (2) clinical evidence of pulmonary infiltrate, such as rales, decreased breath sounds, or dullness in response to percussion; and (3) infiltrates present on chest roentgenogram. To be included, a case of bronchiolitis required the following: (1) fever, (2) respiratory rate over 45/min, (3) wheezes on clinical examination, and (4) respiratory distress. Control children were drawn from those who presented to the outpatient clinic for well-child care, had no acute infectious disease (eg, upper respiratory tract infection, otitis media, gastroenteritis, or conjunctivitis), and had no history (by interview and chart review) of LRTI. Acute dermatologic conditions were not excluded, and 6 controls did have *Candida* diaper rash, impetigo, or dermatitis. Patients who by chart review had a history of asthma, prematurity, ventilator dependency, or congenital heart disease were ineligible to be either cases or controls.

One control patient was matched by age and sex with each case. Cases and controls were considered suitable matches if they were the same age (within 0.5 months). Over an 8-week period from January 4 to February 27, 1988, 81 cases and 69 controls met our

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inclusion and exclusion criteria. From these we were able to construct 58 age- and sex-matched pairs. The 23 unmatched cases were similar in age and sex distribution to matched cases, but no appropriate matches were available in the pool of 69 potential controls.

## Collection of Data

The adult caretaker presenting with the child was interviewed. This was nearly always a parent or grandparent. Using a structured questionnaire, one of two interviewers determined the primary source of energy for heat and cooking in each household. Other environmental factors reported included recent (ie, within 2 weeks in the home) respiratory illness exposures, number of persons in the household, number of rooms, other home characteristics (eg, dirt floor, running water), use of humidification methods, presence or absence of cigarette smoke in the home, and presence or absence of pets. Translators were utilized when necessary.

## Statistical Analysis

All analyses performed on the data set preserved the matched study design. For each factor, a fourfold table was constructed summarizing the number of pairs in which both the case and control were exposed (designated as A), case exposed and control not exposed (B), case not exposed and control exposed (C), and neither case nor control exposed (D). The odds ratio is B/C and is the maximum likelihood estimate, based solely on the discordant pairs. This ratio serves as an estimate of the relative risk in the matched analyses.[25] McNemar's test[26] is an asymptotic test of significance as to whether the odds ratio is equal to 1 (indicating no associated risk). To evaluate the effect of several covariates simultaneously, the conditional logistic regression model was used. Estimation of the modes was based on the maximum likelihood methods described by Breslow and Day[27] and was performed using the microcomputer software package EGRET.[28] Factors were entered into the regression model in a stepwise fashion, and their respective $\beta$ coefficients were tested to see if they significantly differed from 0 (indicating no association). Odds ratios may be computed by exponentiating the coefficients of the resultant model and serve as estimates of the relative risk for that particular factor while adjusting for other covariates in the model. Confidence intervals are formulated by exponentiating: $\beta \pm 1.96$ (SE).

## RESULTS

Fifty-eight age- and sex-matched pairs of children were analyzed. Ages ranged from 2 weeks to 24 months. The prevalence of environmental risk factors is demonstrated in Table 1. Forty-nine case families (84%) and 33 control families (57%) had a WBS in their home. In 21 pairs (36%), the case member utilized a WBS as a primary heating source while the control member did not; in only 5 pairs (9%) did the control member rely on a WBS for heat while the case member did not (odds ratio, 4.2; $P = .0012$). Coal as an adjunctive fuel did not influence the risk of LRTI as long as a WBS was also employed.

The mothers of significantly more case than control children reported recent respiratory illness exposures (odds ratio, 3.7; $P = .002$), primarily acute illnesses of other children in the home or extended family. Case children also more frequently had a family history of asthma (odds ratio, 3.3; $P = .046$), 14 children (24%) vs 7 children (12%). Cigarette smoking was infrequent in these Navajo families, with only 3 cases (5%) and 8 controls (14%) having cigarette smoke in the home (odds ratio, 0.4; not significant). Interestingly, the use of humidifiers, vaporizers, or pans of boiling water to humidify air in the home was not associated with protection from LRTI. Neither of the indexes of crowding (number of people in household or number of rooms) was associated with a greater risk of respiratory illness. Although only a few families had dirt floors in their homes, children in these families were more likely to be ill ($P = .016$), and, alternatively, there was a trend for those who had running water in the home to be protected against LRTI (odds ratio, 0.5; $P = .061$).

## Multiple Logistic Regression

The following factors were evaluated in the conditional logistic model: WBS, family history of asthma, recent respiratory illness exposure, and presence of running water in the household. These covariates were found to be statistically significant or approaching significance ($P < .07$) in the univariate analyses and contained substantial numbers of discordant pairs in the data. As shown in Table 2, the final model only contained main effects of WBS and recent exposure. Tests of interaction between the different combinations of covariates were performed, and the results were nonsignificant. Thus, only the presence of a WBS in the home and recent exposure to other ill children were independently associated with the current episode of LRTI.

## COMMENT

We investigated risk factors for acute LRTI in young American Indian children and found that those living in homes with a WBS have a higher risk of clinical bronchiolitis and pneumonia than age- and sex-matched controls. These results are consistent with those of Honicky et al[22,23] and Kossove.[24] Such increased risk may be due to indoor air

**Table 1.—Presence of Risk Factors in Case-Control Pairs of Navajo Children**

| Factor | Cases, No. (%) | Controls, No. (%) | Odds Ratio* | P* |
|---|---|---|---|---|
| Wood-burning stove for heat | 49 (84) | 33 (57) | 4.2 | .001 |
| Humidification† | 45 (78) | 44 (76) | 1.1 | .500 |
| Recent respiratory illness exposure | 28 (48) | 12 (21) | 3.7 | .002 |
| Cigarettes in home | 3 (5) | 8 (14) | 0.4 | .113 |
| Pets in home | 44 (76) | 39 (67) | 1.5 | .212 |
| Family history of asthma | 14 (24) | 7 (12) | 3.3 | .046 |
| >7 people in home | 19 (33) | 12 (22) | 1.8 | .143 |
| 1-Room home | 14 (24) | 12 (21) | 1.2 | .416 |
| Running water | 34 (59) | 43 (74) | 0.5 | .061 |
| Dirt floor | 7 (12) | 1 (2) | ... | .016 |

*Odds ratios and *P* values are based on case-control matched-pair analysis (McNemar's test).
†Humidifier, vaporizer, water pans.

**Table 2.—Conditional Logistic Model**

| Term | Coefficient | SE | Odds Ratio | 95% Confidence Interval | *P* |
|---|---|---|---|---|---|
| Wood-burning stove | 1.58 | 0.53 | 4.85 | 1.69-12.91 | .003 |
| Respiratory illness exposure | 1.44 | 0.50 | 4.23 | 1.58-11.30 | .004 |

pollution, heating variability, and/or other factors and may be influenced by variables such as the type and availability of fuel, ventilation, and insulation and WBS location in the home. Studies of outdoor air pollution and LRTI have had conflicting results.[2,8,20] Differences between outdoor and indoor air pollution may relate to the quantity of pollutants and/or duration of exposure, an especially pertinent factor in young children confined to the house. Coal use in the stove did not vary between study and control groups. The other factor associated with LRTI in our logistic regression model was recent respiratory illness in other siblings, a well-known risk factor for bronchiolitis.

The associations with dirt floors and lack of running water in the home, significant in bivariate analyses, could be a reflection of socioeconomic status. Low socioeconomic status has been associated with respiratory symptoms.[19,20] However, other socioeconomic indicators, such as crowding or number of rooms in the house, did not appear to discriminate between groups in our population. Other studies have failed to find a correlation between LRTI and socioeconomic indicators, such as mother's education, number of bathrooms, and formal education achieved by the head of household.[8,11,15,23] Lack of running water and dirt floors may be associated with an increased risk of infection and, thus, are not independent of recent infectious disease exposure.

A family history of asthma has been associated with childhood LRTI in some studies and not in others.[10,12,24] Sims et al[14] concluded that environmental rather than inherited factors are the most likely link between severe respiratory illness in infancy or chronic or recurrent respiratory illness in adult life. Others found that LRTI before age 2 years and family history of respiratory allergy are equivalent risks.[9] In this study, family history of asthma did not contribute independently to risk, suggesting that such a history may simply potentiate or modify the occurrence of LRTI when environmental factors such as a WBS are also present.

Surprisingly, neither cigarette smoking nor humidification were related to occurrence of LRTI. Since ambient cigarette smoke is acknowledged to cause respiratory symptoms in young children, the American Academy of Pediatrics discourages smoking around children less than 2 years of age.[17] The lack of correlation in our study likely reflects the extraordinarily low rate of smoking in this population, with only 9% of homes having a smoker in residence. Honicky et al[23] noted no relationship between humidifiers and respiratory symptoms in children. Humidification lowers air particulate matter and reduces dry air respiratory tract irritation. However, the impact of home humidifying techniques in this desert environment is uncertain.

One possible source of bias in our study is our selection of controls from clinic attenders, who may not be representative of all Navajo and Hopi children. Except for those with minor dermatologic complaints, we limited our controls to those being seen for routine well-child care. Well-child clinic attenders may represent a more mobile or higher socioeconomic group of Navajo and Hopis, perhaps decreasing the likelihood that their families relied on a WBS in the home. However, Public Health Service data indicate that over 90% of children born at Tuba City Hospital complete their routine immunizations, suggesting that the well-child population is, in fact, representative.

It is also possible that our control population was contaminated by children who did indeed have a previous episode of LRTI. Since some medical records were incomplete and since many children had also been seen at other clinic sites, we relied heavily on the mother's memory to exclude previous LRTI. If, however, some children with previous LRTI were included in the control group, it would constitute a conservative bias, tending to minimize the differences between study groups.

Finally, interviewing by nonblinded observers may have biased the study. The use of a highly structured questionnaire with a multiple-choice format and standard conventions for accepting data (eg, entering the caretaker's first response to a question) were designed to decrease the potential for this bias but could not eliminate it entirely.

Further studies will require more specific assessment of the cause of lower respiratory tract symptoms to discriminate among infectious, allergic, and irritant phenomena. Likewise, additional studies should employ more direct environmental data; for example, direct analyses of indoor pollutants, smoke content, house and stove ventilation, and specific substances used as fuel. Leaderer et al[29] suggested methods to measure indoor pollutants via monitoring data and daily-use diaries.

In conclusion, our study demonstrates that southwestern American Indian children living in homes heated with a WBS have an increased risk of LRTI independent of recent exposure to others with respiratory illness in the home. This may be an important modifiable risk factor in such traditional rural communities.

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