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Respiratory Effects of Wood Heat: Clinical Observations and Epidemiologic Assessment

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An increasing number of families in the United States are converting to woodburning stoves in an effort to reduce winter heating bills. Woodburning stoves operate as a contained combuster of wood and produce a variety of pollutants as byproducts of combustion. Although technological advances have reduced emissions to some degree, even the most efficient woodburning stoves emit hazardous pollutants directly into the home when the stove is operating and the door is opened to add wood. The question arises as to whether pollutants are accumulating in homes where woodburning stoves are used as a source of heat. This issue is especially important considering the trend to increase home insulation and overall airtightness in an effort to conserve energy and reduce heat loss. This paper reviews the clinical case report that first postulated an association of recurrent chest illness with woodburning stove exposure and summarizes the findings to date on respiratory effects of wood heat for young children.

Introduction

An increasing number of families in the United States are converting to woodburning stoves in an effort to reduce winter heating bills (*1,2*). Documented hazards associated with the use of woodburning stoves include accumulation of carbon monoxide as well as an increased number of burn injuries and house fires (*3,4*). This paper reviews the clinical case report that first postulated an association of recurrent chest illness with woodburning stove exposure (*5*) and summarizes our findings to date on respiratory effects of wood heat for young children (*6–9*).

Recurrent pneumonia, bronchitis, upper respiratory infection, tachypnea, chronic coughing, and wheezing in young children are frequently associated with a family history of atopy, recurrent exposure to viral illnesses in siblings of school age, or exposure to a number of sources of indoor air pollution, such as parental smoking, cooking with gas fuel, or having urea-formaldehyde foam insulation (*10–18*). One possible etiological factor that is neither commonly elicited in medical histories nor well documented in the literature is the use of wood for indoor heating.

Woodburning stoves operate as a contained combuster of wood and produce a variety of pollutants as byproducts of combustion. Although technological advances have reduced emissions to some degree, even the most efficient woodburning stoves emit hazardous pollutants directly into the home when the stove is operating and the door is opened to add wood. Therefore, the question arises as to whether pollutants are accumulating in homes where woodburning stoves are used as a source of heat. This issue is especially important when one considers the trend to increase home insulation and overall airtightness in an effort to conserve energy and reduce heat loss (*3*).

Case Report*

During the winter of 1980, clinical observations at the Pediatric Chest Clinic of the Michigan State University Clinical Center suggested an increase in the number of preschool children presenting with lower respiratory tract illness whose history included a recent change to indoor heating with a woodburning stove. In several of these children there were no discernible coexisting factors.

A representative case involves that of a 7-month-old male hospitalized for increasing respiratory distress, right middle lobe pneumonia, and a choking-apneic episode. The child had been in good health from birth until 3 months of age. In the late fall of 1980 he started having episodes of cough and wheezing. He was seen by an allergist at that time but there were no positive findings for allergies.

Subsequently, his primary care physician initiated antihistaminic and decongestive therapy as well as several courses of antibiotics. This therapy failed to resolve his condition and by December 1980, at age 5 months, the child began the first of 4 hospitalizations for wheezing and pneumonia (Fig. 1).

Each time the child was admitted to his local hospital, the symptoms of wheezing and cough abated. Each time he was

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*The case report is adapted from Honicky et al. (*5*).

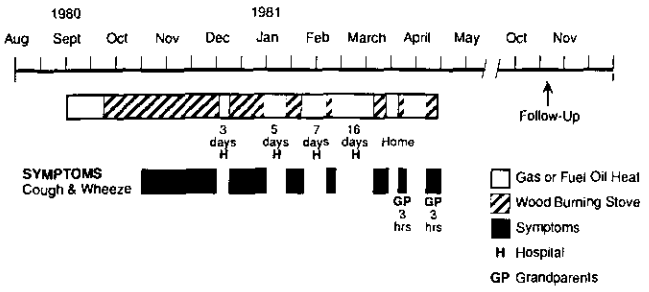

FIGURE 1. Exposure to woodburning stove and symptom occurrence.

discharged from the hospital, his symptoms reoccurred at home within 12 hr. The child would then be treated with a vaporizer and decongestants, but symptoms progressed until he was readmitted to the hospital. The severity of illness and length of stay increased with successive hospitalizations.

The child slept in his own bedroom located 20 ft from the living room. Before this, in the early fall, a fuel oil furnace that was vented to the outside of the home had been used. Because the child had been sick, the only other place he had stayed with any frequency was in the home of his grandparents who also used a woodburning stove as the primary source of heat.

In late January 1981, a 4-year-old sibling began going to nursery school, the mother began working, and the child stayed at the home of the grandparents. The family used electricity as the primary source of energy for cooking. There was no family history of tobacco smoking, asthma, tuberculosis, or other chronic respiratory diseases. Other members of the family did not notice any specific eye irritation. However, complaints of irritation to the nose and throat were ascribed to low environmental humidity. The father had allergies to pollen and animal dander.

Between the third and fourth hospitalizations, the child was seen at the Pediatric Pulmonary Clinic. A chronologic history revealed that the patient's symptoms began several weeks after the family had purchased and installed a woodburning stove as the primary source of heat.

At the outpatient visit in February 1981, the physical examination was noncontributory. Findings from his chest roentgenogram were abnormal, showing hyperinflation, peribronchial cuffing, and infiltrates of the perihilar, right middle lobe, and lingular regions. Results of a sweat chloride test and an esophogram were normal. Bronchodilator therapy was started, and the patient was sent home.

However, the patient's symptoms progressed until he was hospitalized for the fourth time for cough, wheezing, and respiratory distress. These symptoms failed to resolve in several days and he began having episodes of coughing and choking-apneic attacks. He was transferred for further evaluation from his local hospital to the Michigan State University Pediatric Respiratory Unit.

At admission, the child's temperature was 38°C, pulse 148 beats/min, respiratory rate 72/min, blood pressure 110/70 mm Hg, and he was in moderate respiratory distress with intercostal and suprasternal retraction and coarse distant breath sounds. No wheezing was heard. Chest roentgenogram showed persistence of hyperinflation, peribronchial cuffing, and lingular and right middle lobe infiltrate. Cultures and serology for bacteria, viruses, Mycoplasma, and pertussis were negative.

Bronchodilators, postural drainage, and antibiotic therapy were started, and in 9 days the patient was afebrile; there was no cough, his sleeping respiratory rate was 30/min, his chest was clear to auscultation, and chest roentgenogram showed little interval change; he was discharged on a regimen of theophylline.

Within 12 hr of returning home, he began coughing and wheezing again and was taken to the home of a neighbor who did not heat with a woodburning stove; again his symptoms abated.

While at the neighbor's home, the patient's family stopped using their woodburning stove and began using the fuel oil furnace again. The patient went back home after 24 hr at the neighbors without a further recurrence of symptoms until he visited for 3 hr with his grandparents on two separate occasions; each time cough and wheeze reoccurred.

At 1 year follow-up, the patient was well and developing normally without medication. The chest roentgenogram showed a few thin streaky densities on the left side; the right side was clear. The family continued to use fuel oil as its primary source of heat.

Epidemiologic Assessment*

Materials and Methods

Clinical observations for this and other cases at the Michigan State University Pediatric Chest Clinic raised the question of whether there might be an association between indoor heating with woodburning stoves and the occurrence of chronic symptoms of respiratory illness. The specific *a priori* hypotheses were that the proportions of children having moderate and severe chronic respiratory symptoms would be significantly greater for children whose homes were heated by woodburning stoves than for children from homes heated by gas, fuel oil, or electricity.

To investigate these hypotheses, 62 children were randomly selected from the 9977 children who had attended the Clinical Center for well-child checks, routine physical examination, immunizations, or illness care between 1976 and 1981. Children were classified at the time of selection according to the type of indoor heating used in their home. Sampling proceeded until 31 children from homes heated by a woodburning stove had been selected. Each of these children was then matched for age, sex, and geographic area of residence with a child from a home heated by conventional means. The latter group of children constituted the "internal comparison" or "control" group.

The sample size of 31 subjects in each group was arrived at based on the intended method of analysis at the 0.05 level of significance. The children in the study all lived within 40 miles of Lansing, Michigan, were between 1 and 7 years of age (the mean being 3.5 years); 97% were white; 60% were boys and 40% girls.

Data were prospectively collected during the winters of 1982, 1984, and 1985 by interviewing children's parents using a structured interview schedule modified from the Epidemiology Standardization Project Children's Questionnaire (*6,19*). Respondents were the subjects' mothers in all but one case. Socio-

*The epidemiological assessment is adapted from Osborne (*6*), Honicky et al. (*7*), and Osborne and Honicky (*8,9*).

demographic data, frequency of physician visits, medical histories, use of humidifiers and air filters, and exposure to parental smoking, cooking fuel, and urea-formaldehyde foam insulation were also collected. Data were analyzed using the nonparametric test of difference between proportions.

Grouping of symptoms into severity categories was as follows. Mild symptoms were defined as usually coughing with colds, having at least 1 episode of cough, at least 1 episode of chest cold during winter. Moderate symptoms were defined as occasionally wheezing with colds, having at least 1 episode of wheezing during winter, and occasionally coughing apart from colds. Severe symptoms were defined as usually coughing at night, coughing 4 days or more per week, and occasionally wheezing apart from colds.

Results

Results indicated that the occurrence of moderate and severe a symptoms was significantly greater ($p < 0.001$) among children from homes heated by woodburning stoves than among controls during all winters (Table 1). There were, however, no significant differences in the occurrence of mild symptoms, which normally occur in young children. Differences between groups increased with increasing symptom severity during each winter (*6–8*).

Findings for specific symptoms in the moderate and severe categories were also significant for all three winters (*6–8*). Of particular interest were differences in the occurrence of at least one episode of wheezing during winter and of severe symptoms of usually coughing at night, coughinf 4 days or more per week, and occasionally wheezing apart from colds (Table 2).

The majority (77%) of study group homes used a woodburning stove as the primary source of indoor heating and the remainder as a supplemental heat source. The majority (77%) of homes in the control group used fuel oil or gas furnaces as the primary souceof heat, thr remainder heated with electric units.

Table 1. Occurrence of mild, moderate, and severe chronic symptoms.[a]

Symptom severity	Percentage in study and control groups								
	1982[a]			1984[b]			1985[b]		
	Study	Control	p	Study	Control	p	Study	Control	p
Mild	100.0	96.8	NS[c]	96.3	85.0	NS	91.7	89.5	NS
Moderate	100.0	29.0	0.0001	92.6	30.0	0.0001	70.8	15.8	0.0001
Severe	83.9	3.2	0.0001	92.6	20.0	0.0001	70.8	5.3	0.0001

[a]From Honicky et al. (*7*).
[b]From Osborne (*6*).
[c]NS, not significant; $p > 0.05$.

Table 2. Occurrence of moderate and severe cough and wheeze symptoms.[a]

Symptom	Percentage in study and control groups								
	1982			1984			1985		
	Study	Control	p	Study	Control	p	Study	Control	p
Cough at night	67.7	3.2	0.0001	85.2	20.0	0.0001	70.8	5.3	0.0001
Cough most days	45.2	0.0	0.0001	55.6	5.0	0.0001	54.2	5.3	0.0001
Wheeze	64.5	16.1	0.0001	29.6	10.0	0.038	41.2	15.8	0.026
Wheeze without cold	54.8	0.0	0.0001	14.8	0.0	0.0010	20.8	0.0	0.0001

[a]From Osborne and Honicky (*8*) and Osborne (*6*).

Analysis of socioeconomic status showed no significant differences ($p > 0.05$) between study and control groups. Medical histories of children and their parents indicated no clinically significant differences. Frequency of physician visits was also not significantly different ($p > 0.05$).

With respect to exposures and equipment known to affect indoor air quality (Table 3), there were no significant differences ($p > 0.05$) between groups for parental smoking or use of urea-formaldehyde foam insulation. About half the homes in each group had at least one parent who smoked regularly in the home, with a slightly greater proportion in the control group. Two homes in the study group had urea-formaldehyde foam insulation. The control group made significantly greater use of gas stoves for cooking, whereas a significantly greater proportion of the study group families cooked with electric stoves ($p < 0.05$).

Regarding equipment that would tend to improve air quality, there was no difference in the use of humidifiers, with about half the homes in each group using at least one humidifier regularly. However, the study group made significantly greater use of air filters ($p < 0.05$).

Discussion

The major hypothesis of this study was that the proportion of children with chronic respiratory symptoms in homes heated by wood would be greater than the proportion in homes not heated by wood. To minimize possible selection bias in the samples, children were randomly selected without regard to reason for visit to the Clinical Center. With respect to the representativeness of the samples, both well and ill children attend the ambulatory health care facility from which the samples were drawn. Since most children present for well-child checks and preventive medicine as well as sick call, it is reasonable to assume that the samples were generally representative of young children receiving standard medical care living in south central Michigan.

The potentially confounding effects of age, sex, and geographic area of residence (as a surrogate for outdoor air pollution levels) were controlled by matching subjects in the study and control groups at selection. The potential effects of socioeconomic status, medical history, frequency of physician visits, cooking with gas, parental smoking, urea-formaldehyde foam insulation, humidifiers, and air filters were assessed in analysis.

Parental smoking, cooking with gas, and urea-formaldehyde foam insulation have been associated with an increase in the frequency of respiratory problems in young children. A number of

Table 3. Exposures and equipment affecting indoor air quality.

Exposure	Percentage		
	Study	Control	p
Parental smoking	48.4	51.6	NS[a]
Cooking fuel			
Gas	19.4	42.0	0.02
Electricity	77.4	58.0	0.05
Kerosene	3.2	0.0	NS
Formaldehyde insulation	6.5	0.0	NS
Humidifier	48.4	48.4	NS
Air filter	25.8	9.7	0.04

[a]NS (not significant), $p > 0.05$.

studies have reported a higher incidence of respiratory illness among children age 5 years and older and a greater incidence of bronchitis and pneumonia in the first year of life among children of smokers as compared with nonsmokers (*10–12*). Children from homes in which gas is used for cooking have been reported to have a greater occurrence of cough, "colds going to the chest," and bronchitis than children from homes where electricity is used (*15,16*). Exposure to formaldehyde has been associated with coughing and shortness of breath (*17,18*).

In the present study, the very similar distribution of parental smoking, the greater use of gas cooking fuel in the control group, and the very low number of homes with formaldehyde insulation suggests that these factors did not play a significant role with respect to differences in the occurrence of respiratory symptoms. Similarly, the equal distribution of humidifiers and the greater use of air filters by the study group suggests that differences in the occurrence of symptoms were not significantly affected by use of this equipment.

Differences in the occurrence of respiratory symptoms were both statistically and clinically significant. The results are consistent with findings previously reported on the occurrence of acute chest illness from 1980 to 1982 (*9*). In that study, children from homes heated with woodburning stoves had a significantly greater occurrence of acute chest illness (especially bronchitis, pneumonia, and upper respiratory infection), a greater proportion of chest illnesses lasting at least 1 week, and a greater proportion of children who were hospitalized for chest illness before 2 years of age. If exposure to a woodburning stove is associated with the occurrence of respiratory symptoms and chest illness, as these findings suggest, then it remains to be determined which aspects of woodburning stove use may be involved.

Indoor heating with woodburning stoves can generate a significant amount of air pollution. Documented pollutant emissions of woodburning stoves include carbon monoxide, nitrogen and sulfur dioxides, respirable particulates, aldehydes (e.g., formaldehyde and acrolein), polycyclic organic compounds, benzo[*a*]pyrene, organic and elemental carbon, and a variety of priority pollutants (e.g., aluminum, calcium, potassium, sodium, sulfur, and silicon) (*20–25*).

Respiration of these compounds could reasonably compromise the ciliated epithelial cells, which are a significant component of the respiratory defense system (*9,26*). The respiratory effects of such exposure would probably be greatest on the smaller, developing airways of young children who are largely confined within the home during winter months.

A number of other factors may affect indoor air pollution from woodburning stoves. These include peak versus average exposure, type of woodburning stove and location within the home, differences in pollutant levels emitted by airtight versus nonairtight woodburning stoves, type and amount of wood burned, degree of home airtightness, indoor temperature fluctuations, and indoor humidity (*6,7,9*).

Data from the present study did not support an association between the occurrence of symptoms and the type of woodburning stove, amount of wood burned, or location within the home; the other factors mentioned above were not assessed. However, it is reasonable to assume that these factors may have some effect.

Conclusions

The findings of this study indicated that young children living in homes heated by a woodburning stove had a greater occurrence of moderate and severe chronic respiratory symptoms than children of the same age and sex who did not live in homes heated with a woodburning stove. Differences in symptom occurrence were not accounted for by medical histories, frequency of physician visits, socioeconomic factors, or exposure to other sources of indoor air pollution investigated in this study and suggest that indoor heating with a woodburning stove may have significant respiratory effects for young children.

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