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HEALTH EFFECTS OF HEATING WITH WOOD: CHEST ILLNESS IN YOUNG CHILDREN AND INDOOR HEATING WITH WOODBURNING STOVES

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ABSTRACT

This study investigated a suspected relationship between the occurrence of chest illness in young children and use of woodburning stoves (WBS) for indoor heating. Data were prospectively collected during the winters of 1980, 1981, and 1982 for 62 mid-Michigan children age one to seven years (31 randomly selected children from WBS-heated homes and 31 controls from homes heated by conventional sources matched for age, sex, and place of residence). The specific a priori *research hypotheses were that the proportion of children having a chest illness would be significantly greater in the WBS group than in the control group, that a greater proportion of WBS group children would have chest illnesses lasting at least one week, and that a greater proportion of WBS group children would be hospitalized before age two years for chest illness.*

Results showed a significant difference ($p < 0.05$) between the WBS and control groups in the proportion of children having a chest illness from 1980–1982 (especially bronchitis, upper respiratory infection, and pneumonia); 39% of the WBS group and 19% of controls had at least one such illness. Further, the WBS group had a greater proportion of chest illnesses lasting at least one week (32% vs. 16%) and a greater proportion of hospitalizations for chest illness before age two years (16% vs. 10%). These differences were not accounted for by medical histories, frequency of physician visits, sociodemographic factors, or exposure to other sources of indoor air pollution investigated in the study (i.e., parental smoking, cooking with gas, urea-formaldehyde foam insulation) and suggest that indoor heating with WBS may be a significant risk factor for chest illness in young children.

INTRODUCTION

The indoor environment is a significant factor in the health of modern populations. Data indicate that urban residents in the United States spend more than 90% of their time indoors and that a majority of the population spends more than 80% of its time indoors. Accompanying this demographic transition has been an increasing concern regarding the quality of indoor air and the presence of hazardous pollutants, whose concentrations are sometimes higher indoors than they are outdoors (Spengler and Sexton 1983; Task Force on Epidemiology of Respiratory Diseases 1980).

The problem of controlling indoor exposures to airborne hazards to the respiratory system has been emphasized by the Task Force of the National Institutes of Health (NIH) on Prevention, Control, and Education for Respiratory Diseases (1977) and by the NIH Task Force on Epidemiology of Respiratory Diseases (1980). While the Task Force reports indicate that the relationship between bronchial asthma and a variety of agents is well-established clinically, this is not true for relationships between other prevalent respiratory problems and exposures to domestic sources of airborne pollutants, many of which result from the application of technologies in the home.

The presence of recurrent pneumonia, bronchitis, upper respiratory infection, wheezing, and tachypnea (rapid shallow breathing) in young children is commonly associated with a family history of atopy, parental smoking, home cooking fuel, or recurrent exposure to viral illnesses in siblings of school age (Bonham and Wilson 1981; Cameron et al. 1969; Colley 1971, 1974; Colley et al. 1974; Glezen and Denny 1973; Leeder et al. 1976; Luguette et al. 1970; Melia et al. 1977; Monto et al. 1971; Norman-Taylor and Dickinson 1972; Speizer et al. 1980). Earlier epidemiological studies on the patterns of occurrence and etiology of respiratory infection in the family related frequency of illness to age, sex, and sociocultural factors such as family size and crowding (Brimblecombe et al. 1958; Dingle et al. 1964; Lidwell and Sommerville 1951). One possible etiological factor that is neither commonly elicited in medical histories nor well documented in the literature is use of a woodburning stove for indoor heating.

An increasing number of families in the United States are converting to woodburning stoves in an effort to reduce their winter heating bills. Estimates indicate that more than one million new woodburning stoves are sold for domestic use in the United States each year and that usage is increasing in all socioeconomic groups (Lipfert and Dungan 1983; Meyers and Schipper 1984; Thompson 1984). The three basic types of woodburning stoves are: freestanding units, fireplace-insert units, and furnace add-on units. Documented hazards associated with the use of woodburning stoves include accumulation of carbon monoxide (especially in newer, more airtight homes) as well as burn injuries and fires (Breysse 1981; Remensnyder and Gryska 1981).

Although several types of woodburning stoves are in use, most of them function similarly to the most popular type—the Franklin stove, invented by Benjamin Franklin in Philadelphia in the 1740s (Harrington 1979; Schneider 1980). The Franklin-type stove operates as a contained combustor of wood, releasing a variety of pollutants into the indoor environment (Butcher and Sorensen 1979; Cooper 1980; Cooper and Malek 1982; Lipfert and Dungan 1983; Moschandreas et al. 1980). While technological advances have reduced emissions to some degree, even the most efficient woodburning stoves emit hazardous pollutants which are released directly

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into the home when the stove is operating and the door is opened to add wood. Therefore, the question arises as to whether by-products of wood combustion 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 (Breysse 1981; Moschandreas et al. 1980).

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 use of a woodburning stove for indoor heating. In several of these children there were no discernible coexisting factors.

The present study was conducted to investigate whether there was a difference in the occurrence of chest illness for young children from homes heated by wood and by conventional means. The specific *a priori* research hypotheses were that the proportions of children having at least one chest illness per year, having chest illness lasting at least one week, and needing to be hospitalized for chest illness before age two years would be greater for children from homes heated by woodburning stoves than for those from homes heated by furnaces or electricity.

METHODS

The population from which samples were drawn for this study consisted of 9977 children one to seven years of age (as of January 1, 1982) who had attended the Michigan State University Clinical Center for well-checks and physicals, immunizations, or illness care between 1976 and 1981 (inclusive). The Clinical Center offers both primary and subspecialty care and is essentially equivalent to a group practice setting for the pediatric population. Sixty-two children who lived within the five-county Greater Lansing area were randomly selected from this population without regard to reason for visit or primary diagnosis at clinic attended. The 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 and then continued until each child in the study group was matched for age, sex, and geographic area of residence with a child from a home heated by conventional means (i.e., gas furnace, fuel oil furnace, or central electric heat). The latter group of children constituted the "internal comparison" or "control" group.

The design employed was a "historical prospective design" (also referred to as a "retrospective-cohort design"), wherein the two groups stratified at selection by type of indoor heating were followed forward in time to determine their illness experience during the three-year period from 1980 to 1982 (Hulley and Cummings 1988; MacMahon and Pugh 1970; Mausner and Kramer 1985). The purpose in matching children in the study and control groups for age, sex, and geographic area of residence was to control for the potentially confounding effects of these variables.

Participants were recruited by a telephone call to their parents, who were informed that the study was being conducted to investigate the occurrence of chest illness in young children from homes with different types of indoor heating; all parents contacted participated in the study. The sample size of 31 subjects in the study and control groups was arrived at based on the intended method of analysis at the 0.05 level of significance. The 62 children in the study all lived within 40 miles of Lansing, MI, were between one and seven years of age (mean, 3.5 years), and were predominantly white (97%); 60% were boys and 40% girls.

Parents of the children were interviewed by telephone using an interview schedule modified from the Epidemiology Standardization Project Children's Questionnaire (Ferris 1978). The questions were self-explanatory and required a yes, no, or number response. Open-ended discussion by parents was permitted during the interview, supplementing information acquired through the closed-ended questions. Interviews were conducted randomly across both groups and respondents were the subjects' mothers in all but one case; the interviewer was not aware of group membership (prior to conducting the interview). Sociodemographic data, frequency of physician visits, medical histories, use of humidifiers and air filters, and exposure to domestic sources of indoor air pollution were also collected.

Data were analyzed to determine the proportion of children having at least one chest illness per year, having chest illnesses that lasted at least one week, and being hospitalized for chest illness before age two years. These outcomes were compared in the study and control groups using the nonparametric test of difference between proportions.

The study and control groups were also compared in terms of medical histories, socioeconomic status, frequency of physician visits, use of humidifiers and air filters, and exposure to three sources of domestically produced indoor air pollution which have been associated with chest illness and the occurrence of respiratory symptoms in young children. These exposures were parental smoking (and smoking in the home by other household members), cooking with gas, and having urea-formaldehyde foam insulation.

RESULTS

The occurrence of chest illness in the study and control groups was appreciably different (see Figure 1). Results showed a significant difference ($p < 0.04$) in the proportion of children having at least one chest illness per year, with twice the proportion in the study group as in the control group (see Table 1). Thirty-nine percent (39%) of children from homes heated by wood had at least one such illness per year compared with 19% of controls, the most commonly reported illnesses being bronchitis, upper respiratory infection, and pneumonia.

The study group also had twice the proportion of chest illnesses lasting at least one week—32% compared with 16%. With respect to hospitalization, 67% more children from homes heated by wood were hospitalized for severe chest illness before age two years—16%, compared to 10% of controls. Further, 40% of children requiring hospitalization in the study group had more than one such episode while none of the control group children were hospitalized for severe chest illness more than once. While differences in the proportions of children with chest illnesses lasting at least one week and requiring hospitalization before age two years were clinically significant, they were not statistically significant at the 0.05 level.

About three-fourths of homes (77%) in the study group used wood as the primary source of indoor heating. Wood was the only source of heat in 13% of homes in the study group. Fifty-eight percent (58%) of woodburning stoves were installed within a major living area. The number of half-cords of wood burned during 1982 ranged from five to 25 with a mean of 12.8 half cords per home.

About three-fourths of homes (77%) in the control group

TABLE 1

Children with at Least One Severe Chest Illness per Year, Chest Illness Lasting at Least One Week, and Hospitalization Before Age Two Years for Severe Chest Illness: Proportions in Study (WBS) and Control Groups, Z-Statistic, and Significance of Differences.

Chest Illness	Proportion (%) WBS Group	Proportion (%) Control Group	Z Statistic	Significance of Difference
At Least 1 Severe Chest Illness/Yr	38.7	19.4	1.72	0.04
Chest Illness Lasting At Least 1 Week	32.3	16.1	1.51	0.06
Hospitalization Before Age 2 Yrs. for Severe Chest Illness	16.1	9.7	0.76	NS*

* NS = Not Statistically Significant.

used fuel oil or gas furnaces as the primary source of heat; the remainder heated with steam, hot water, or a built-in electric unit.

Analysis of socioeconomic status as reflected by number of bathrooms in the home (as a surrogate for household income) and education of head of household showed no statistically significant differences ($p > 0.05$) between study and control groups. In the study group, 58% had one to one-and-a-half bathrooms, 32% had two, and 10% had three or more compared with 52%, 38%, and 10%, respectively, in the control group. Regarding the highest level of education for head of household, comparisons of the study group to the control group were as follows: 26% in each group graduated from college or had post-graduate training, 29% (study

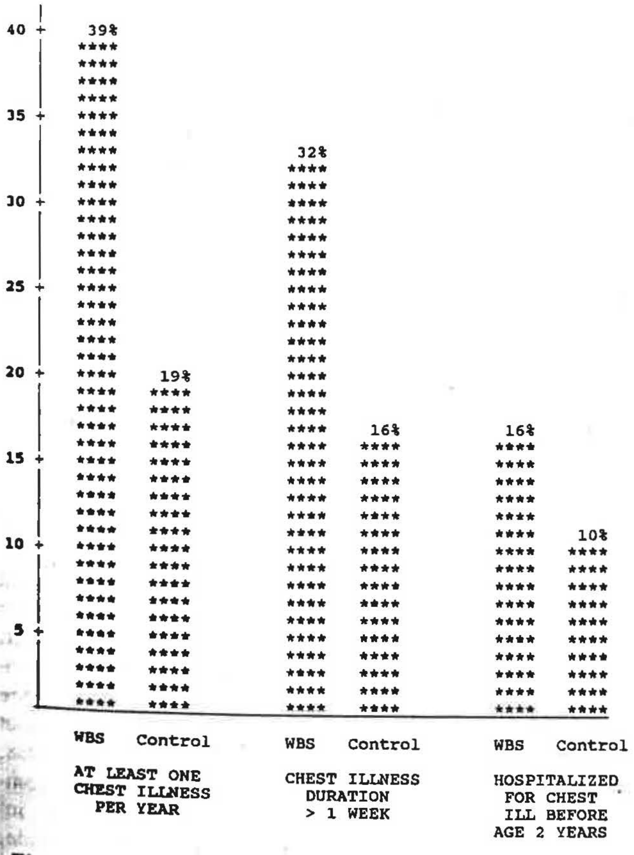

Figure 1 *Proportions (as percent) of children with outcomes in study (WBS) and control groups*

TABLE 2

Exposure to Parental Smoking, Cooking Fuel, Urea-Formaldehyde Foam Insulation, and Use of Humidifiers and Air Filters in Study (WBS) and Control Groups: Proportions (as percent), Z-Statistic, and Significance of Differences.

Exposure/Equipment	Proportion (%) WBS Group	Proportion (%) Control Group	Z Statistic	Significance of Difference
Parental Smoking*	48.4	51.6	−0.25	NS
Cooking Fuel:				
Gas	19.4	42.0	−1.99	0.02
Electricity	77.4	58.0	+1.66	0.05
Kerosene	3.2	0.0	+1.01	NS
Urea-Formaldehyde Foam Insulation	6.5	0.0	+1.47	NS
Humidifier(s) Used	48.4	48.4	0.00	NS
Air Filter(s) Used	25.8	9.7	+1.70	0.04

NS = Not Statistically Significant.

* At least one parent or other adult household member smoking tobacco regularly in the home.

group) vs. 23% (control group) had some college, 35% in each group graduated from high school, and 10% vs. 16% did not graduate from high school.

Medical histories of children and their parents indicated no clinical data which would predispose children in one group to a greater or lesser occurrence of chest illness than the other group. Frequency of physician visits was also not significantly different ($p > 0.05$), with a mean of three visits per child during the winter of 1982 among study group children compared with four visits among controls.

With respect to exposures and equipment known to affect indoor air quality, there were no significant differences between groups ($p > 0.05$) in parental smoking or use of urea-formaldehyde foam insulation (see Table 2). 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 (52% vs. 48% in the study group); the mean number of packs of cigarettes smoked per day by smokers in the study group was 1.8 compared with 1.5 in the control group. A small proportion of homes in the study group had urea-formaldehyde foam insulation. The control group made significantly greater use of gas stoves for cooking ($p < 0.02$; 42% vs. 19%) while a significantly greater proportion of the study group families cooked with electric stoves ($p < 0.05$; 77% vs. 58%) (see Table 2).

Regarding equipment which would tend to improve air quality, there was no difference ($p > 0.05$) in the use of humidifiers, with 48% of homes in each group using at least one humidifier regularly. However, the study group made significantly greater use of air filters ($p < 0.04$; 26% vs. 10%).

DISCUSSION

The major hypothesis of this study was that the proportion of children experiencing chest illness in homes heated by wood would be greater than the proportion in homes not heated by wood. In constructing the research design to test this hypothesis, particular attention was paid to controlling for potential confounding variables and sources of bias.

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.

Regarding possible selection bias and the representativeness of the samples, both well and ill children attend the ambulatory health care facility from which the samples were drawn. It is probable that more ill than well children present for care in the Pediatric Offices at the Clinical Center, as for any group pediatric practice. However, since most children present for yearly checks and preventive medicine, such as immunizations, as well as sick call (Behrman and Vaughan 1987), it is reasonable to assume that the samples are generally representative of young children receiving standard medical care living in south central Michigan.

Data were collected by telephone interview, which has the disadvantage that it can result in a lower reporting of illness frequency than actually occurs, a type of informant bias (Jordan et al. 1953; Monto et al. 1971; Monto and Ullman 1974). However, since a standardized instrument was used for data collection (i.e., the Epidemiology Standardization Project Children's Questionnaire), it is reasonable to expect that any underreporting of symptoms occurred to the same extent in both the study and control groups. In addition, participants were recruited for a general study of the effects of indoor heating (rather than a specific study of effects of heating with wood), thereby minimizing any informant bias which might be associated with a study of a particular type of indoor heating. Finally, the method of analysis favored the control group (i.e., made it more difficult to conclude there was a significant difference between groups) by comparing outcomes categorized as having occurred or not occurred rather than comparing mean number of episodes (which were considerably higher in the study group).

Several factors in the home have been associated in the literature with an increase in the frequency of recurrent respiratory tract illnesses in young children, especially parental smoking, cooking with gas, and urea-formaldehyde foam insulation. A number of studies have indicated that there is a greater occurrence of respiratory illness among children age five and older of smokers as compared with non-smokers (Bonham and Wilson 1981; Cameron et al. 1969; Luguette et al. 1970; Norman-Taylor and Dickinson 1972). There may also be a greater occurrence of bronchitis and pneumonia in the first year of life among children whose parents smoke as compared with children of non-smokers (Colley et al. 1974). Although the amount of tobacco smoked in subjects' presence was not recorded in the present study, the very similar distribution of cigarette smoking in the home (48% of parents from wood-heated homes, mean 1.8 packs/day; 52% of control parents, mean 1.5 packs/day) suggests that this factor probably did not play a significant role with respect to differences in the occurrence of chest illness in the two groups.

Children from homes in which gas is used for cooking have been found to have a greater occurrence of cough, "colds going to the chest," and bronchitis than children from homes where electricity is used (Melia et al. 1977; Speizer et al. 1980). Gas was used for cooking in a significantly higher proportion of homes in the control group. Therefore, while the greater use of gas stoves among controls may have been a confounding factor acting to reduce differences between groups, it seems reasonable to conclude that the part played by type of cooking fuel did not account for observed differences in the occurrence of chest illness.

Exposure to formaldehyde has been associated with a variety of detrimental effects, including symptoms of respiratory illness such as coughing and shortness of breath (Ashford et al. 1984; Grafstrom et al. 1983; Levin and Purdom 1983; Michigan Department of Public Health 1982; Nation's Health 1984; Sun 1984; Wildavsky et al. 1984). The very low number of homes with urea-formaldehyde foam insulation (n = 2) suggests that this factor did not have a significant effect.

It is of interest that the same proportion of homes in each group was equipped with humidifiers and that the study group made significantly greater use of air filters. This equipment would tend to decrease indoor concentrations of particulate pollutants and reduce respiratory tract irritation due to dry air. Despite the lack of humidity or particulate readings in the homes, the distribution of this equipment between groups suggests that differences in the occurrence of chest illness were not significantly affected by use of humidifiers or air filters.

The use of wood for space heating in the United States contributes significantly to outdoor levels of pollutants (especially particulates) in many residential areas (Cooper 1980; Lipfert and Dungan 1983; Sexton et al. 1986). The use of fireplaces and woodburning stoves in the home has also been shown to increase indoor levels of various pollutants (Cooper and Malek 1982; Moschandreas et al. 1980; Sexton et al. 1986; Traynor et al. 1987). Differences have also been found in the amounts of pollution emitted by airtight vs. non-airtight stoves (Traynor et al. 1987). Hence, depending on the type of woodburning stove, its use in the home may introduce a significant amount of air pollution.

During the winter months, young children (especially preschoolers) tend to be confined within their homes for a great part of the day and definitely at night. Consequently, these children constitute a group which is maximally exposed to the indoor environment. Those children from homes with high levels of indoor air pollution during the winter months would be more likely to manifest outcomes of exposure, including acute chest illness.

The difference in the occurrence of chest illness in the present samples was both statistically and clinically significant. While outcome measures reported in this study were not season-specific, the results are consistent with findings previously reported by the authors on the occurrence of chronic symptoms of respiratory illness during the winter of 1982, where in the study group 77% and 84% had moderate and severe symptoms, respectively, as compared with 29% and 3% in the control group (Honicky et al. 1985; Osborne 1985; Osborne and Honicky 1986). If exposure to a woodburning stove is associated with the occurrence of acute chest illness and chronic respiratory symptoms, as these findings suggest, then it remains to determine which aspect(s) of woodburning stove use may be involved.

It is possible that respiratory illness in young children living in wood-heated homes may be associated with indoor air pollution from the combustion of wood. If this is correct, a reasonable mechanism could be pollutant-induced compromise of the ciliary action of ciliated epithelial cells, which are a significant component of the immune system throughout the tracheobronchial tree (Baum 1974; Fraser et al. 1988; Fishman 1988). Pollutant emission by-products of wood combustion that have been reported for woodburning stoves include carbon monoxide, nitrogen dioxide, sulfur dioxide, respirable particulates, aldehydes (such as acrolein), polycyclic organic compounds, benzo(alpha)pyrene, elemental carbon, and a variety of priority pollutants and elements found in priority pollutants (e.g., aluminum, calcium, potassium, sodium, sulfur, and silicon) (Cooper 1980; Cooper and Malek 1982; Moschandreas 1980; Sexton et al. 1986; Traynor et al. 1987).

If any of these by-products of wood combustion are linked with illness occurrence, then the questions arise whether illness might be associated with a number of other factors related to heating with wood, including peak vs. average exposure, type of stove and location within the home, type and amount of wood burned, degree of airtightness of the home, and the temperature and relative humidity of the home. Peak exposure would occur during periods of maximum daily use and when the stove door is opened to add wood, while average exposure involves a time-weighted averaging of air exchange between the stove unit and the indoor environment. Although present data do not support an association between stove location or type of stove and the occurrence of chest illness, it may be that these factors have some effect, as might the type(s) and amount of wood burned. The air envelope around the house, the volume and degree of airtightness of the house, and the reintroduction of outdoor pollution from woodburning stoves to the indoor environment may also affect indoor air quality.

Another pertinent variable may be fluctuations in temperature in wood-heated homes as compared with homes heated by conventional means, which usually have a thermostat keeping indoor temperatures in a fairly narrow range. The relative humidity in the home may be another important factor, especially at night when woodburning stove use (which reduces indoor humidity) is greatest for indoor heating. The potential impact of these factors has not been determined but some are clearly candidates for affecting the occurrence of respiratory health outcomes.

In conclusion, the findings of this study indicated that young children living in homes heated by a woodburning stove were more likely to develop chest illness than children of the same age and sex who did not live in homes heated with a woodburning stove. Differences in the occurrence of chest illness were not accounted for by medical histories, frequency of physician visits, sociodemographic factors, or exposure to other sources of indoor air pollution investigated in this study and suggest that indoor heating with a woodburning stove may be a risk factor for chest illness in young children.

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DISCUSSION

Carl N. Lawson, LRW Engineers Inc., Tampa, FL: Your tests were accomplished in an area where heat is really required. Do you feel the same results would be found in areas where humidity is quite high and electric heat is the prime element for heating?

J.S. Osborne III, Kalamazoo Center for Medical Studies, Kalamazoo, MI: Duration and intensity of exposure are probably important factors with respect to health outcomes in young children. However, about 25% of the children whose homes were heated with wood in our study used a woodburning stove as a supplemental heat source (rather than primary) and they too manifested increased occurrence of chest illness. We believe relative humidity in the home is an important factor and, in areas of higher outdoor humidity, it would be reasonable to expect this to somewhat offset the reduction of indoor humidity from use of a wood-burning stove, depending on the volume and degree of airtightness of the home.

Marian L. Heyman, Hartford Steam Boiler Inspection and Insurance Co., Hartford, CT: Since a number of homes employed humidification systems, was consideration given to the possibility of contaminated humidifiers and/or humidification system components with microorganisms as factors in respiratory illness in children?

Osborne: Forty-eight percent of the homes in each group used at least one humidifier regularly. This is not surprising given the ages of the children in the study, the duration of Michigan winters, and the low indoor humidity during the heating season. It is reasonable to assume that humidifiers served as a mechanism of transmission for microorganisms and that this is reflected in the control group as well as the study group. The mechanism(s) whereby exposure to a woodburning stove may affect respiratory illness have not yet been determined, though it would be reasonable to speculate that pollutant-related compromise of the ciliated epithelial cells of the respiratory tract might alter susceptibility to infection from any source. However, the comparable distribution of humidifiers in the two groups suggests their use did not account for observed differences in the occurrence of chest illness.