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Wood stove heating, asthma and allergies

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Abstract In two German studies household wood or coal stove use was negatively associated with atopic sensitization and allergic rhinitis in childhood. Wood stove heating is strongly related to 'traditional lifestyle' and therefore subjected to confounding factors possibly yet not known. The study was conducted to study these factors and the independent impact of early exposure to wood stove heating on subsequent asthma and atopic disease. In a questionnaire survey among 10 667 Finnish university students aged 18–25 years, we investigated the association between wood stove heating at age 0–6 years and asthma and allergies up to young adulthood. Adjustment was made for factors related to the heating system and atopic disorders by using multivariate regression. Unadjusted lifetime prevalence rates for physician-diagnosed asthma, allergic rhinoconjunctivitis, atopic dermatitis and self-reported wheezing were lower among subjects with wood stove heating compared to other heating systems. There was a significant negative association between childhood wood stove heating and allergic rhinitis or conjunctivitis in the univariate model (OR 0·61, 95% CI 0·61–0·91), but not for the other diseases. The significant association disappeared in the multivariate analysis after adjusting for various family, indoor and outdoor (adjusted OR 0·96, 95% CI 0·77–1·20) factors. The association between wood stove heating and allergic rhinoconjunctivitis was mainly confounded by childhood residential environment, especially the farm environment. Farm environment was found to be the main confounding factor related to association between wood stove heating and asthma, and atopic diseases.

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INTRODUCTION

The indoor environment is considered to be of great importance in allergic sensitization and in the development of atopic disorders, such as asthma. Many studies have focused on airborne indoor allergens and pollutants. Early exposure to allergens, especially to house dust mites, has been shown to enhance sensitization and childhood asthma in warm and humid climate (1). However, in northern cold climate sensitization to pets is of major importance in predicting adult asthma (2). Early indoor allergen exposure alone does not seem to be related to childhood asthma, wheeze or bronchial hyper-responsiveness (3). The association between an indoor source of combustion, tobacco smoke, and childhood and adult onset asthma is quite well confirmed (4,5), but the relation between parental smoking and sensitization in children is weak and inconsistent (6).

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Wood or coal heating emitting combustion products indoors was negatively associated with hay fever, atopic sensitization and bronchial hyper-responsiveness among rural Bavarian primary school children (7), and with dry cough and wheezing among pre-school children in Australia (8). In a German ISAAC-study (International Study on Asthma and Allergies in Childhood) among 5–8- and 12–15-year-olds, the negative association between wood or coal stove heating and occurrence of allergic rhinitis symptoms was shown in eastern Greifswald, but not as clearly in western Münster (9). Possible enhanced ventilation and more traditional lifestyle related to wood or coal stove heating was suggested as an explanation. In a case-control study, main heating methods, regardless of their ability to enhance ventilation, did not predict childhood asthma (10). Traditional environment, on the other side, has been related to low prevalence of sensitization, possibly due to exposure to bacterial endotoxins (11,12) or environmental mycobacteria (13), favouring non-atopic T-helper 1 type immunity.

Earlier reports have shown that there are more respiratory infections in children exposed to wood stove heating (14,15). High particulate contaminant levels, typical in residences with wood or coal heating (16,17), could

explain the harmful health effects of wood stove heating. In fact, among adult Chinese never-smokers, high fine particle levels indoors were positively associated with chronic respiratory illness but, not with physician-diagnosed asthma (18).

In Finland, where the heating season lasts at least 8 months, the impact of heating system on respiratory and other allergic diseases may be relevant. We studied the association between early exposure to different heating systems, pets and residential environment and the occurrence of asthma and allergies up to early adulthood.

MATERIAL AND METHODS

Study subjects

In winter 1995–1996 a postal self-administered questionnaire was sent to all new university students (n=14202), aged 18–25 years. A total of 10 667 students responded, of these 4168 (39%) were men and 6509 (61%) women. Response rate was 75·0%, 66·5% among men, and 81·8% among women. Mean age of the respondents was 20·9 years.

Methods

Students replied to validated questions (16) on the occurrence of physician-diagnosed (1) asthma, (2) allergic rhinitis and/or conjunctivitis, (3) atopic dermatitis and (4) self-reported wheezing during their lifetime. Wheezing was defined as the occurrence of attacks of shortness of breath with wheezing, apart from respiratory infections. Validation of the diagnostic questions among the present study population has been reported earlier (19).

Of all the heating systems, wood as heating fuel was clearly most strongly associated with the diseases. Therefore, subjects with wood stove heating at age 0–6 years were analysed against a reference group with central heating, electrical heating, and some less frequently used systems, such as under-floor heating and roof radiation heating at age 0–6 years. Subjects with wood stove heating at age 7–18 years or later were excluded from the reference group.

Factors in early childhood included in the multivariate models were selected by preliminary analysis on possible confounding factors, and were as follows: presence of furred pets or birds, smoking of a family member daily indoors and day-care outside the home at age 0–2 years. Residential environment was included as a variable on three levels: living on a farm, living in a rural non-farm or in an urban residence at age 0–6 years (20). In addition, gender, parental education, parental history of asthma or atopic disease, and number of older children were included (20).

Statistical analysis

Pearson's chi-square was used to compare the characteristics of the houses and the households with and without wood stove heating. The results were regarded significant below P=0·05. Factors related to family, indoor and residential environment in early life, that were significantly associated with wood stove heating were used in the univariate analyses as explanatory variables for the diseases (Table 1). In addition, sex and parental atopy were analysed. Finally, variables with significant relation to at least one of the diseases were regarded in the multivariate models (21), and associations were expressed as odds ratios (OR) with 95% confidence intervals (CI). Confidence intervals excluding 1·0 were regarded as significant. A separate analysis between the main confounding factor, the residential environment, and wood stove heating was conducted. Statistical computing was performed with SAS System for Windows, release 6.12/1996.

RESULTS

The majority of the study population was born in the middle of the 1970s. According to the responses received, during the respondent's age period of 0–6 years, 76·3% (7082) of their households had central heating 12·5% (1160) electrical heating, 8·5% (793) wood stove heating, and 2·5% (242) under-floor heating or roof radiation heating. These accounted for 99·8% of all the heating systems. Houses with wood as heating fuel were significantly more often single family or detached houses than apartments (778 *vs*. 12), had been built earlier than 1970 (595 *vs*. 198) and were mainly wooden houses (671 *vs.* 124).

Subjects in the households with wood stove heating lived significantly more often with regular smokers and furred pets at the age of 0–2 years, had more older siblings, and day-care outside the home at age 0–2 years was uncommon (Table 1). Living on a farm or in a rural non-farm residence and low parental education was frequent among subjects with wood stove heating (Table 1).

Lifetime prevalence of asthma, wheezing, allergic rhinitis and/or conjunctivitis were lower among subjects with wood stove heating at age 0–6 years (Table 1). In the univariate analysis there was a statistically significant negative association between wood stove heating and allergic rhinitis and/or conjunctivitis (18·6% *vs.* 23·4%, $P<0·01$, crude odds ratio 0·74, 95% CI 0·61–0·91, Table 2), but not in the other diseases. The negative association between wood stove heating and allergic rhinitis and/or conjunctivitis did not remain significant (OR 0·96, 95% CI 0·77–1·20) in the multivariate analysis, when adjustment was made for family, indoor and outdoor factors (Table 2). On the other hand, the negative association between living on a farm (20), but not in a rural non-farm,

or urban residence at age 0–6 years and allergic rhinitis and/or conjunctivitis remained highly statistically significant (OR for farm compared to rural non-farm 0·61, 95% CI 0·50–0·75, $P < 0·0001$). Neither were there any significant associations between pet-keeping at age 0–2 years and the diseases (data not shown) in the multivariate

Table 1. Characteristics of the subjects with and without wood stove heating in the household during the early childhood. Finnish university students aged 18–25 years, 1995–1996

	Wood stove heating at age 0–6 years % (*n*)	Other heating system at age 0–6 years % (*n*)	*P*-value*
Parental education (*n*=9603)	*n*=769	*n*=8834	
Low	53·2 (409)	27·0 (2384)	
Middle	34·3 (264)	36·7 (3245)	
High	12·5 (96)	36·3 (3205)	0·001
Parental atopy (*n*=9785)	*n*=787	*n*=8998	
	39·4 (310)	40·8 (3669)	0·448
Number of older siblings in the family (*n*=9815)	*n*=793	*n*=9022	
0	44·0 (349)	53·9 (4866)	0·001
1	32·9 (261)	34·1 (3077)	0·497
2	14·2 (113)	8·5 (763)	0·001
3	5·3 (42)	2·3 (209)	0·001
≥4	3·5 (28)	1·2 (107)	0·001
Residential environment at 0–6 years (*n*=9088)	*n*=745	*n*=8343	
Farm	51·7 (385)	7·9 (663)	
Non-farm rural	19·4 (145)	12·0 (1001)	
Urban	28·9 (215)	80·1 (6679)	0·001
Passive smoking at 0–2 years (*n*=9777)	*n*=790	*n*=8987	
	25·9 (205)	21·2 (1904)	0·002
Furred pets in the home at 0–2 years (*n*=9736)	*n*=787	*n*=8949	
	49·2 (387)	18·5 (1652)	0·001
Day-care outside the home at 0–2 years (*n*=9717)	*n*=792	*n*=8925	
	3·9 (31)	11·3 (1008)	0·001

**P* value calculated using Pearson's chi-square and using all available data.

Table 2. Impact of heating system on physician-diagnosed asthma, allergies and wheezing up to 18–25 years of age among Finnish students. Subjects with wood stove heating in the household compared to subjects with other heating systems

	Wood stove heating*	Other heating system				
	Prevalence % (*n*/*N*)‡	Prevalence % (*n*/*N*)‡	Crude OR	95% CI	Adjusted OR§	95% CI
Allergic rhinitis and/or conjunctivitis (*n*=8545)	18·6 (130/700)	23·4 (1833/7845)	0·74	0·61–0·91	0·96	0·77–1·20
Asthma (*n*=8510)	4·0 (28/700)	4·6 (356/7810)	0·87	0·59–1·29	0·99	0·65–1·53
Wheezing (*n*=8546)	6·4 (45/700)	7·0 (549/7846)	0·91	0·67–1·25	1·01	0·71–1·42
Atopic dermatitis (*n*=8480)	17·9 (125/697)	18·7 (1458/7783)	0·95	0·78–1·16	1·02	0·82–1·28

*Wood stove heating at age 0–6 years.

†Any other heating system, e.g. electric heating, central heating, under-floor or roof radiation heating at age 0–6 years and no wood stove heating at age 0–18 years.

‡Complete multivariate data.

§Adjusted by multiple logistic regression for sex, parental atopy, socioeconomic status of the family, number of older siblings in the family, residential environment at age 0–6 years (farm, non-farm rural, urban), passive smoking at age 0–2 years, furred pets in the home at age 0–2 years and day care outside the home at age 0–2 years.

models, even though adjustment was made for parental atopy. Parental asthma and atopy was the strongest risk factor for asthma (OR 2·39, 95% CI 1·14–1·89), allergic rhinoconjunctivitis (OR 1·84, 95% CI 1·28–2·65) and atopic dermatitis (OR 1·55, 95% CI 1·09–2·21) but not for wheezing. Day-care outside the home at age 0–2 years significantly increased the risk of allergic rhinoconjunctivitis (OR 3·16, 95% CI 1·44–6·9) and wheezing (OR 3·6, 95% CI 1·34–9·94), but not the risk of asthma or atopic dermatitis. On the contrary, family size with large number of older sibling was related to lower occurrence of allergic rhinoconjunctivitis, and asthma or wheezing (20).

The unadjusted prevalence rates of physician-diagnosed asthma, atopic disorders and wheezing in relation to residential environment and heating system are summarized in Table 3. Those who had lived on a farm and had wood stove heating had the lowest prevalence of allergic rhinoconjunctivitis and asthma. Impact of environmental factors, such as pets, parental education and passive smoking on atopic diseases were separately analysed among subjects from farms with and without wood stove heating. In these analyses, the effect of environmental factors on diseases was similar in both farm subgroups (data not shown). Based on those and the multivariate analyses, the farm environment seemed to be the main confounding factor related to the wood stove heating among rural residents. Among childhood urban residents, wood stove heating showed significant protective impact on allergic rhinitis and/or conjunctivitis (18·1 *vs*. 24·0%, P=0·047), but not in the multivariate model (Table 3). In contrast among subjects who had lived on a farm, wood stove heating was related to significantly higher prevalence of atopic dermatitis (19·5 *vs*. 14·5%, P=0·034, and the result was also confirmed in the multivariate model, (adjusted OR 1·44, P=0·049, Table 3).

DISCUSSION

In Finland, at the end of the 1970s, wood stove heating was more common in rural areas, in families with low parental education and large sibships. In epidemiological studies, all these factors have been related to less frequent allergies. In the present study two other factors associated with wood stove heating: exposure to pets (3,22,23) and passive smoking in early life (6), have given conflicting findings regarding to subsequent atopic diseases. In the present study, early exposure to wood stove heating did not predict the occurrence of asthma, wheezing or atopic disease, when all these confounding factors were taken in account.

Among the rural Bavarian child population, there was a negative association between wood stove or coal heating and allergic sensitization, bronchial hyper-reactivity and

Table 3. Prevalence and risk for physician-diagnosed allergic rhinitis and/or conjunctivitis, asthma, atopic dermatitis and self-reported wheezing up to age 18–25 years among Finnish university students. Percentages according to the residential environment and the heating system at age 0–6 years

		Prevalence of atopic diseases % (n†)		Wood stove heating related risk of atopic disease			
	Residence at age 0–6 years	Wood stove heating	No wood stove heating	OR	P-value	Adjusted OR‡	P-value
Allergic rhinitis and/or conjunctivitis	Farm	16·1 (385)	15·5 (663)	1·04	0·81	1·09	0·67
	Rural non-farm	26·2 (145)	22·1 (1001)	1·25	0·27	1·32	0·20
	Urban	18·1 (215)	24·0 (6678)	0·70	0·047*	0·75	0·11
Asthma	Farm	3·1 (385)	3·6 (660)	0·85	0·66	0·85	0·69
	Rural non-farm	6·9 (145)	5·2 (996)	1·34	0·41	1·43	0·34
	Urban	3·7 (215)	4·5 (6649)	0·82	0·59	0·90	0·79
Wheezing	Farm	6·5 (385)	5·3 (663)	1·25	0·41	1·14	0·66
	Rural non-farm	4·8 (145)	7·6 (1001)	0·62	0·23	0·62	0·25
	Urban	8·4 (215)	7·0 (6679)	1·21	0·44	1·19	0·50
Atopic dermatitis	Farm	19·5 (384)	14·5 (656)	1·43	0·034*	1·44	0·049*
	Rural non-farm	20·3 (143)	18·0 (990)	1·16	0·51	0·94	0·81
	Urban	14·9 (215)	19·0 (6629)	0·75	0·13	0·75	0·15

*P<0·05

†Using all available data, n=total number of subjects belonging to each category.

‡Complete data, adjusted for sex, parental atopy, socioeconomic status of the family, number of older siblings in the family, and passive smoking, furred pets in the home and day-care outside the home at age 0–2 years.

parental report of hay fever, when pets, passive smoking, parental education and number of household members were included in the analysis (7). Frequent respiratory infections induced by combustion products (15,16) and their possible protective role against atopy could be suggested as an explanation (24). The occupation of the parents was not known, but they were suspected to be farmers. In another German study among children, the negative association between symptoms of allergic rhinitis and wood stove or coal heating seemed to explain partially the differences in prevalence rates of allergic rhinitis in eastern and western parts of Germany (7). In the present study, the 'protective' impact of a farm environment in childhood also remained highly significant with regards to allergic rhinoconjunctivitis (20) in the present multivariate models, where the heating system and exposure to pets at early age were added.

The finding is also in line with a study among Swiss schoolchildren, reporting that farmer's children had less allergic rhinitis and sensitization (25). However, in a separate analysis among subjects with childhood urban residence, a small protective impact of wood stove heating against allergic rhinoconjunctivitis could be suggested, which weakly supports the earlier findings of the protective role of wood stove heating against allergic rhinitis and sensitization (7,8). In rural environments such an association was not shown, possibly due to stronger effect of other factors, such as farming.

In the present study, there was no clear protective effect of farm environment or wood stove heating on atopic dermatitis. In a stratified analysis, however, combination of wood stove heating and farming, was associated with high occurrence of atopic dermatitis compared to lowest occurrence when exposed only to farming. Although the finding is weak, and quite contradictory, it could be explained by the effect of wood stove heating-enhanced ventilation on the dryness of atopic dermatitis-prone skin.

Finland is ideal to study the impact of heating systems is because the heating season is extremely long, and people spend a considerable time indoors. However, in the current cross-sectional study among adults aged 18–25 years a remarkable reporting bias could be introduced. It would most probably concern remembering the type of heating, and exposure to animals and tobacco smoke at an early age (0–2 years). The latter two factors, known to increase asthmatic symptoms, might be more easily reported by asthmatics. In addition, the impact of early exposure to pets could be biased due to avoidance of pets in families with symptomatic subjects. On the other side, misclassification of heating system would concern diseased and non-diseased equally, because the association between heating with allergies is not commonly known. Some bias might be related to the study population, i.e. first-year university students. In Finland, the possibilities of further education are equal. In 1996, 6·6% of the Finnish population were farmers. In the present study population, 10·6% of the subjects had lived on a farm at age 0–6 years, which shows that children of farmers are well represented among university students, and possible bias related to residential environment and study population is small.

In conclusion, the negative association between wood stove heating and allergic rhiniconjunctivitis was confounded mainly by the residence variable in the multivariate models. Only a weak protective effect of wood stove heating against allergic rhinoconjunctivitis among urban residents was suggested. Further studies on factors that are related to traditional farm environment, such as exposure to microbes and their products, e.g. bacterial endotoxins (11,12) and environmental mycobacteria (13), that may have the potential to protect against atopic diseases seems worth pursuing.

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