#4409

HEALTH EFFECTS OF INDOOR EXPOSURE TO NO_2, ENVIRONMENTAL TOBACCO SMOKE AND HOME DAMPNESS*

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The effect of indoor exposure to nitrogen dioxide, environmental tobacco smoke and home dampness on respiratory health was studied over a period of two years in a population of Dutch, non-smoking children.

There was no relationship between exposure to nitrogen dioxide in the home and respiratory symptoms. Respiratory symptoms were found to be associated with exposure to tobacco smoke and home dampness. There was a weak, negative association between MMEF and exposure to nitrogen dioxide. FEV_1, PEF and MMEF were all negatively associated with exposure to tobacco smoke. Home dampness was not associated with lung function.

There were no clear relationships between exposure and the development of lung function over the study period. The development of respiratory symptoms was associated with exposure to ETS and, to a lesser extent, home dampness.

INTRODUCTION

The relationships between indoor exposure to nitrogen dioxide (NO_2), environmental tobacco smoke (ETS), home dampness and the respiratory health of children have been the subject of several studies (1-7). Most studies on health effects of indoor NO_2 performed so far have not measured NO_2 exposure directly, but have used surrogate variables like source presence instead. The resulting exposure misclassification may have obscured real effects on respiratory health. Effects of exposure to ETS on children's lung function as well as respiratory symptoms have been documented more unequivocally (4), although several questions remain. For example, the importance of in utero exposure for effects observed later in childhood has not been established. Recently, several cross sectional, epidemiologic studies have documented an association between home dampness and indicators of respiratory health of children (5-7). To what extent exposure to house dust mites and/or moulds is responsible for these associations is still an open question, and in one study (7), the validity of the association itself has been questioned on the grounds that it could have been caused by responder bias.

In this paper, the combined effect of exposure to three different environmental factors in the home (NO_2, environmental tobacco smoke and home dampness) on respiratory health of children will be summarized. In addition, some specific issues concerning ETS and home dampness will be discussed. The design of the study has emphasized measurement of NO_2 exposure in all study homes. Also, a cross sectional as well as a

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longitudinal component has been included. Data collection started in the fall of 1984, and ended in the spring of 1987.

SUBJECTS AND METHODS

In 1984, the parents of 997 children living in a rural area in the south-east of the Netherlands were invited to let their child participate in the study. At that time, the children were 6-10 years old. Of these children, 832 (84%) participated. Two years later, in 1986, the parents of these children were invited again. Of the original 832, 88 had left the area, and 42 children from one school could not be included because the director of their school refused to participate again. Of the remaining 702, 614 (88%) participated again. In addition to these, all 612 other children aged 6-12, attending the same schools at that time, were invited to participate in this second phase of data collection. Of these, 437 (71%) agreed. The lower participation rate among this group is due to the fact that some of the refusing parents of the population invited in 1984 were included in it. So, 1051 children participated in the second part of the study (19861987), of whom, as mentioned, 614 participated in the first part of the study (1984/1985) as well.

In January 1985 or in January 1987, the weekly average NO_2 concentration was measured in most of the homes (living room, kitchen and bedroom), using Palmes diffusion tubes. Details of the protocol used in our laboratory are given in (8). Earlier work had indicated that the within-home variability of NO_2 is small compared to the between-home variability (9). Detailed information on other methods used in the study is provided in (10). Children who were not of North West European origin, or who said they smoked were excluded from further analysis.

As NO_2 exposure estimate, the average concentration of kitchen, living room and bedroom was chosen because earlier work had indicated that this measure is highly reproducible, and that it is closely associated with personal NO_2 exposure as measured with personally worn diffusion tubes (11). The distribution of the home average NO_2 concentrations was found to be highly right-skewed, and to prevent a few outliers to unduly influence the results, the NO_2 concentrations were grouped into four categories. The categories were coded 0 for NO_2 concentrations between 0 and 20 $\mu g/m^3$ (reference category), 1 for NO_2 concentrations between 21 and 40 $\mu g/m^3$, 2 for NO_2 concentrations between 41 and 60 $\mu g/m^3$, and 3 for NO_2 concentrations over 60 $\mu g/m^3$. This variable was included in further analyses.

Of all homes in the study, 42.4% were in the first category, 34.3% in the second category, 13.4% in the third category, and 9.9% were in the highest category.

The questionnaire information on smoking habits was condensed into a dichotomous variable denoting whether or not tobacco products were being smoked inside the home of the child on a daily basis. Smoking in pregnancy was used as an adjustment variable in some of the analyses, to investigate to what extent effects of current exposure to ETS remained after taking smoking in pregnancy into account.

The questionnaire information on home dampness was condensed into a three category variable having a value of 0 when no damp stains or mould growth was reported, a value of 1 when damp stains or mould growth was reported, and a value of 2 when both were reported.

RESULTS

Of the 1051 participating children in 1986/1987, 985 were non-smokers of North West European origin. Of all children, 66.0% were exposed to ETS in the home, 15.3% had a vented kitchen geyser in the home, and 16.5% had an unvented kitchen geyser in the home. In 14.8% of the homes, damp stains were reported, and in 9.1% of the homes, mould. For 876 of the 985 children, complete NO_2 measurement data and information on home characteristics was available.

Out of the population of 985 children, 775 (79%) had complete data on respiratory symptoms, confounders and exposure variables. 634 (64%) children had complete data on lung function, confounders and exposure variables.

Table 1 shows the association respiratory symptoms and exposure to NO_2, ETS and home dampness. No association was found between indoor NO_2 and the prevalence of respiratory symptoms. Exposure to ETS and home dampness was associated with a higher prevalence of symptoms. COUGH was significantly associated with ETS exposure and with living in a damp house. The associations between ETS exposure and WHEEZE and ASTHMA, and between the combined symptom variable and home dampness were of borderline significance. The combined symptom variable was also significantly associated with ETS exposure.

Table 1 Associations between respiratory symptoms and exposure to NO_2, ETS and dampness in the home in a population of 775 Dutch children of 6-12 years old

Symptom	Odds Ratio for exposure to: ETS	NO_2	Dampness
COUGH	2.34* [1.03 - 5.31][a]	1.02 [0.72 - 1.45]	1.72* [1.08 - 2.75]
WHEEZE	1.83# [0.97 - 3.44]	0.87 [0.64 - 1.18]	1.25 [0.80 - 1.94]
ASTHMA	1.94# [0.91 - 4.15]	0.74 [0.50 - 1.10]	1.25 [0.74 - 2.12]
One or more symptoms	2.03* [1.15 - 3.60]	0.95 [0.73 - 1.24]	1.38# [0.95 - 2.02]

a 95% confidence limits
\# $0.10 > p > 0.05$ (two sided) * $p < 0.05$ (two sided)

Adjustment for smoking in pregnancy (Table 2) did not influence the odds ratios found for home dampness. The odds ratios for ETS exposure were somewhat attenuated, but the relationship with the combined symptom variable remained statistically significant.

Table 2 Associations between respiratory symptoms and exposure to NO_2, ETS and dampness in the home in a population of 773 Dutch children of 6-12 years old, adjusted for maternal smoking in pregnancy

Symptom	Odds Ratio for exposure to: ETS	NO_2	Dampness
COUGH	1.93 [0.82 - 4.58][a]	1.02 [0.72 - 1.45]	1.82* [1.13 - 2.92]
WHEEZE	1.80# [0.93 - 3.49]	0.87 [0.64 - 1.18]	1.26 [0.80 - 1.96]
ASTHMA	1.76 [0.79 - 3.93]	0.73 [0.49 - 1.09]	1.28 [0.75 - 2.18]
One or more symptoms	1.90* [1.04 - 3.46]	0.95 [0.73 - 1.24]	1.41# [0.96 - 2.06]

a 95% confidence limits
$0.10 > p > 0.05$ (two sided) * $p < 0.05$ (two sided)

Table 3 shows the associations between lung function and indoor NO_2 concentrations, ETS exposure and home dampness. The effect is expressed as percentage difference in lung function between children in one of the exposed groups compared with children in the reference group. The table shows that the association between ETS and lung function was significantly negative for FEV_1, PEF and MMEF. The magnitude of the estimated effect on MMEF was about 5%. The associations between indoor NO_2 exposure and lung function were negative for FEV_1, PEF and MMEF, but only the coefficient for MMEF reached borderline statistical significance. There was no association between home dampness and lung function. Only for MMEF, a negative coefficient was estimated.

There was no clear relationship between lung function growth and exposure. The development of respiratory symptoms over the study period was associated with exposure to ETS and, to a lesser extent, home dampness, but not to NO_2.

If symptoms are over-reported in damp homes and not in dry homes, one would expect common associations between symptoms and lung function to be attenuated in children living in damp homes relative to children living in dry homes. The relationships between symptoms and lung function were investigated separately for children living in damp homes and children living in dry homes. Symptomatic children living in damp homes had lung functions that were as reduced, compared to non-symptomatic children, as symptomatic children living in dry homes (table 4).

Table 3. Associations between lung function and exposure to NO_2, ETS and dampness in the home in a population of 634 Dutch children of 6-12 years old

Lung function Variable	% difference associated with exposure to: ETS	NO_2	Dampness
FVC	-0.6 [-2.1, 0.9]a	0.1 [-0.6, 0.9]	0.7 [-0.5, 1.9]
FEV_1	-1.6* [-3.2, -0.0]	-0.2 [-1.0, 0.6]	0.2 [-1.2, 1.6]
PEF	-2.8* [-4.9, -0.6]	-0.5 [-1.7, 0.6]	0.2 [-1.6, 2.1]
MMEF	-4.9* [-8.4, -1.1]	-1.8# [-3.7, 0.2]	-1.8 [-4.9, 1.4]

a 95% confidence limits
0.10 > P > 0.05 (two sided) * p < 0.05 (two sided)

Table 4 Associations between respiratory symptoms and lung function in a population of children of 6-12 years old, living in mouldy and non-mouldy homes

Lung function Variable	% difference associated with resp. symptoms for children living in: mouldy homes	homes without mould
FVC	5.2 [-1.2, 12.0]a	-0.1 [-2.8, 2.7]
FEV_1	-0.5 [-8.0, 7.8]	-3.7 ** [-6.5, -0.9]
PEF	-5.9 [-13.0, 1.8]	-3.8 # [-7.5, 0.4]
MMEF	-13.4 [-27.7, 3.7]	-13.7 *** [-19.2, -7.7]

a 95% confidence limits # 0.10 > P > 0.05 (two sided)
** p < 0.01 *** p < 0.001

DISCUSSION

In this study, we have been unable to document that exposure to NO_2, as measured with Palmes' diffusion tubes in the home, is associated with respiratory symptoms or lung function in children. Only the association between NO_2 and MMEF reached borderline statistical significance. As mentioned, only 9.9% of homes had weekly home average indoor NO_2 concentrations of more than 60 $\mu g/m^3$. Earlier work had shown that the ratio between peak concentrations observed in the home for a number of hours each week, and weekly average concentrations is in the order of 4 to 6.

The percentage of homes in which subjects were regularly exposed to peak concentrations of more than about 300-400 $\mu g/m^3$ NO_2 was therefore probably limited. Another explanation could be, that the exposure variables used do not adequately represent exposure to the short term peak concentrations of NO_2 which might be more harmful than long term average concentrations. Weekly average concentrations may not be associated with short term peak concentrations any better than simple home characteristics like the presence of certain combustion sources.

As in other studies, we have found clear associations between exposure to ETS and the respiratory health of children. Adjustment for smoking in pregnancy did not remove these associations, which supports that they do not just simply mirror harm due to smoking in pregnancy.

This study also supports that living in damp homes is associated with respiratory morbidity. From the calculations presented in table 4, it can be concluded that this asssociation is not due to over-reporting of symptoms by subjects who are aware to be living in a damp home.

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