Gas Cooking and Smoking Habits and the Risk of Childhood and Adolescent Wheeze

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The authors investigated the risk of wheezing illnesses in relation to contemporaneous pollutant exposures (gas cooking, heating, and smoking) in childhood and adolescence in a cohort of 2,289 United Kingdom subjects. Data from two questionnaires assessing wheezing at ages 7–8 and 15–17 years and one questionnaire on current and past pollutant exposures at age 16–18 years were studied (1987–1996). The 1,868 subjects returning all three questionnaires were divided into three groups representing childhood (10.5%), adolescent (10.9%), and persistent (i.e., both; 16.3%) wheezing and compared with 1,165 controls (62.4%) without wheezing. The estimated risks of childhood wheezing were increased by exposure to any gas in childhood (odds ratio (OR) = 1.47, 95% confidence interval (CI): 1.05, 2.04) and exposure to a gas hob in childhood (OR = 1.56, 95% CI: 1.13, 2.16) and were increased further in those persistently exposed. Risk of persistent wheezing in adolescence was paradoxically reduced by exposure to a gas hob (OR = 0.67, 95% CI: 0.50, 0.91), possibly because of selection avoidance. Contemporaneous exposure to combined smoking by both parents was associated with wheezing in all groups (odds ratios ranged from 1.62 (95% CI: 1.06, 2.46) to 1.93 (95% CI: 1.10, 3.38)). Maternal smoking alone was associated with persistent wheezing and with both childhood (OR = 1.90, 95% CI: 1.06, 3.39) and persistent (OR = 2.18, 95% CI: 1.15, 4.14) wheezing if smoking occurred throughout childhood and adolescence. The authors conclude that exposures to gas cooking and smoking in childhood and adolescence increase the overall risk of wheezing.

Abbreviations: CI, confidence interval; OR, odds ratio.

Young children can spend over 90 percent of their time in the home (1). Exposure to cigarette smoke and to indoor air pollutants such as nitrogen dioxide from gas heating and cooking appliances may be associated with an increased incidence of respiratory symptoms in children (2) and adults (3). However, the evidence has been inconsistent, and the nature of the relevant upper and lower respiratory tract symptoms is unknown (4).

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† Deceased.
years (5). We sought to determine, through the study of a cohort of United Kingdom adolescents over a period of 9 years (6, 7), whether exposure to indoor pollutant sources in childhood and adolescence was associated with respiratory symptoms at those times.

MATERIALS AND METHODS

Study subjects

We conducted three questionnaire surveys in an original cohort of 3,542 randomly selected children from Southampton, United Kingdom (see figure 1 for details on response rates and losses to follow-up). In 1987, we undertook a study of respiratory symptoms in 3,542 children aged 7–8 years. The first survey, a survey of childhood wheeze, was sent to parents at that time; the parents of 3,187 children responded. The questions posed to the parents were “Has your child wheezed in the past 12 months?” and “Has your child ever wheezed?”. For the present analyses, childhood wheezing was categorized as current (in the last 12 months), past (ever, but not in the last 12 months), and current and past (both) (6). In 1995, in a second survey, we investigated wheeze in the same population (3,033 adolescents who were then aged 15–17 years; 2,289 responded) using the same questions on wheeze. For the present analyses, adolescent wheezing was categorized as current (in the last 12 months), past (ever, but not in the last 12 months), and current and past (both). “Persistent wheeze” was defined as a positive response to wheeze questions in both adolescence and childhood. The precise classification of responses is provided in table 1. The same questionnaire ascertained data on history of atopic disorders (hay fever and eczema), the presence of smokers in the household, paternal occupation, and current smoking habits (by means of a separate confidential smoking questionnaire sent to each adolescent in a separate reply-paid envelope) (7). In 1996, we conducted a third survey by postal questionnaire in the same cohort of 2,289 adolescents (then aged 16–18 years) to obtain data on cooking, heating, and smoking habits and personal and lifestyle factors contributing to indoor pollution.

For the present study, we categorized the 1,868 children who responded to all three surveys into four mutually exclusive groups based on the presence or absence of wheezing in childhood and adolescence (table 1):

1. Childhood wheezing—reported wheezing (past and/or current) was present at any time up to age 7–8 years but not at any time up to age 15–17 years.
2. Persistent wheezing—reported wheezing (past and/or current) was present at any time up to age 7–8 years and at any time up to age 15–17 years.
3. Adolescent wheezing—no reported wheezing at any time up to age 7–8 years but reported wheezing (past and/or current) at age 15–17 years.
4. No reported wheezing—no reported wheezing at any time up to age 7–8 years or at any time up to age 15–17 years (control group).
We acknowledged the possibility that our classification of subjects who reported wheezing at age 7–8 years (either “past” or “current”) but also reported “past” (but not “current”) wheezing at age 15–17 years could be referring to wheezing that only occurred in childhood (and not adolescence). Therefore, we further stratified subjects with persistent wheezing into those considered to have “clearly persistent” wheezing (wheezing at any time at age 7–8 years and “current” wheezing at age 15–17 years) and those considered to have “indeterminate persistent” wheezing (wheezing at any time at age 7–8 years and “past” but not “current” wheezing at age 15–17 years). We carried out subanalyses in combinations of these groups to determine whether exposures at certain times were related to past or contemporaneous symptoms.

Study design

The questionnaire under consideration was sent in 1996 when the adolescents were 16–18 years old, followed by a reminder after 6 weeks. This questionnaire actually consisted of two separate questionnaires, the first ascertaining current exposure in 1996 (in adolescence) and the second asking parents and children to recall exposures contemporaneous to the administration of the first survey in 1987 (in childhood). We inquired about exposures in 1996 but made the assumption that they were also current in 1995 when the second survey was administered. It was anticipated that adolescents would be able to fill in a questionnaire related to 1996, but since the 1987 questionnaire related to retrospective factors pertaining to their childhoods, it was included simultaneously and also addressed to the parents. As in the previous survey, each adolescent was encouraged to help the parents complete the questionnaire.

Detailed information was sought on the home with regard to cooking, heating, and smoking habits (see Appendix). In order to validate the exposure data, we randomly recruited a subgroup of 78 adolescents who had had wheezing symptoms in the previous 12 months for objective assessment of indoor pollution by active monitoring (as part of a different study to be described elsewhere, results of which are currently unpublished). Ethical approval for this study was granted by the Southampton University Hospitals Local Joint Ethics Committee, and informed consent was obtained from the parents of each adolescent.

Statistical analyses

Responses to the questionnaire were coded and double-entered. Differences in the prevalence of indoor factors across the symptom groups were analyzed by maximum-likelihood polytomous logistic regression using StatView, version 5.1 (SAS Institute, Inc., Cary, North Carolina), and Stata, version 8 (Stata Corporation, College Station, Texas). Univariate and multivariate analyses were performed using the symptom group as a dependent variable and other cooking, smoking, and heating factors as independent variables. Parental smoking was stratified into four groups: neither parent ever smoked, only the mother smoked, only the father smoked, or both parents smoked at the same time. Each model included mutual simultaneous adjustment

### Table 1. Classification of study participants at age 16–18 years (n = 1,868) according to the presence or absence of wheezing symptoms at ages 7–8 years and 15–17 years, Southampton, United Kingdom, 1987–1996

<table>
<thead>
<tr>
<th>Wheezing at age 7–8 years</th>
<th>Wheezing at age 15–17 years</th>
<th>No. of participants</th>
<th>Wheezing classification (symptom group)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Past*</td>
<td>Current†</td>
<td>Past</td>
<td>Current</td>
</tr>
<tr>
<td>1 1 0 0</td>
<td></td>
<td>60</td>
<td>Childhood wheezing</td>
</tr>
<tr>
<td>1 0 0 0</td>
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<td>133</td>
<td>Childhood wheezing</td>
</tr>
<tr>
<td>0 1 0 0</td>
<td></td>
<td>3</td>
<td>Childhood wheezing</td>
</tr>
<tr>
<td>1 1 1 0</td>
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<td>57</td>
<td>Persistent wheezing</td>
</tr>
<tr>
<td>1 1 1 1</td>
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<td>153</td>
<td>Persistent wheezing</td>
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<tr>
<td>1 1 0 1</td>
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<td>0</td>
<td>Persistent wheezing</td>
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<td>1 0 1 0</td>
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<td>42</td>
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<td>Persistent wheezing</td>
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<td></td>
<td>68</td>
<td>Adolescent wheezing</td>
</tr>
<tr>
<td>0 0 0 1</td>
<td></td>
<td>0</td>
<td>Adolescent wheezing</td>
</tr>
<tr>
<td>0 0 1 1</td>
<td></td>
<td>135</td>
<td>Adolescent wheezing</td>
</tr>
<tr>
<td>0 0 0 0</td>
<td></td>
<td>1,165</td>
<td>No wheezing (controls)</td>
</tr>
</tbody>
</table>

* Past = “Have you ever wheezed?” (1 = yes, 0 = no).
† Current = “Have you wheezed in the last 12 months?” (1 = yes, 0 = no).
for gender, personal atopic status, and social class as defined by paternal occupation (nonmanual = classes I, II, and IIIa; manual = classes IIIb, IV, and V) (8). Associations between several variables and wheezing in childhood, adolescence, or both (persistent wheezing) were compared with those in the control group, who did not report wheezing. We further stratified persons with persistent wheezing into those with “clearly persistent” and “indeterminate persistent” wheezing and compared them with the control group. Results were tabulated as odds ratios and 95 percent confidence intervals, using log-likelihood ratio tests, based on the hypothesis that the odds ratios for all symptom groups were the same. All odds ratios represent estimates of the risk of wheezing but are hereafter referred to as “risks” for brevity.

We first examined the presence of risk factors in childhood (questionnaire related to 1987) and the risk of wheezing in children with contemporaneous symptoms (childhood and persistent wheezing symptom groups only). Secondly, we examined the presence of risk factors in adolescence (questionnaire related to 1996 but assumed to be current in 1995) and the risk of wheezing in subjects with contemporaneous symptoms (persistent and adolescent wheezing symptom groups only). Thirdly, we examined whether changes in cooking or smoking habits made between childhood and adolescence affected the association with wheeze across contemporaneous symptom groups. In these analyses, the risk of wheezing was further stratified by whether factors were present in childhood only (in 1987 but not in 1996), in adolescence only (in 1996 but not in 1987), or at both times (in both 1987 and 1996) in relation to a control group in whom the factors were absent in both childhood and adolescence (not present in 1987 and not present in 1996). Fourthly, current personal smoking among adolescents was similarly stratified in relation to a control group who did not smoke. Finally, using Fisher’s exact test in 2 × 2 tables, we tested whether the proportions of subjects in each wheezing and control group were significantly different in subjects who had never used gas for cooking and subjects who had used gas cooking fuel for 15 years or less. We similarly tested the difference in proportions of subjects who had never used gas for cooking and those who had used gas cooking fuel for more than 15 years. All p values are expressed as either nonsignificant ( > 0.05), ≤ 0.05, ≤ 0.01, or ≤ 0.001.

For the purposes of this study, we refer to a “gas hob” as an indoor open gas-fired stove, as opposed to an “oven,” which is considered a closed gas-fired stove. Electric storage heating systems use low-cost electricity to store energy in heat-retaining bricks. These give off heat slowly by radiation or convection of warm air and are designed to keep dwellings warm for the whole of the following day. They are not known to emit gaseous pollutants.

RESULTS

Response rates, symptom groups, and confounding factors

Of the 2,289 adolescents contacted in 1996, 1,868 (81.6 percent; 52.7 percent of the original cohort) (figure 1) responded (male:female ratio 1.13:1). They comprised 196 adolescents (10.5 percent) with childhood wheezing, 203 (10.9 percent) with adolescent wheezing, 304 (16.3 percent) with persistent wheezing, and a control group of 1,165 (62.4 percent) who did not report wheezing (table 1). Data on personal history were similar to those obtained from previous questionnaires sent to the same population. Responses to questions on exposure to gas cooking were associated with greater nitrogen dioxide concentrations for the subgroup of 78 subjects participating in active monitoring. The median values were 49.0 μg/m² if gas was used for cooking and 21.7 μg/m² if electricity was used for cooking (Mann-Whitney U test: p < 0.001).

We performed univariate and multivariate analyses to assess the risk of wheeze in relation to gender, personal atopy, and social class across the different symptom groups. The mutually adjusted odds ratios are given in tables 2 and 3. Personal atopy was associated with increased risks of childhood, persistent, and adolescent wheezing (odds ratios were 1.63 (95 percent confidence interval: CI) 1.18, 2.24), 14.77 (95 percent CI: 10.43, 20.90), and 7.11 (95 percent CI: 4.99, 10.13), respectively). Manual social class was associated with adolescent wheezing (odds ratio (OR) = 1.76, 95 percent CI: 1.26, 2.45), and female gender was associated with a reduced risk of persistent wheezing (OR = 0.62, 95 percent CI: 0.46, 0.82). All three confounding factors were included in all subsequent logistic regression models related to childhood exposures. Adolescent smoking was not associated with persistent (OR = 1.07, 95 percent CI: 0.80, 1.4) or adolescent (OR = 1.00, 95 percent CI: 0.71, 1.39) wheezing. Adolescent smoking was further included with atopy, gender, and social class in all subsequent logistic regression models related to exposure in adolescence.

Symptom groups and risk factors

Gas cooking and heating. Childhood exposure. The risk of childhood wheezing was increased with use in childhood (1987) of any gas and a gas hob for cooking (odds ratios were 1.47 (95 percent CI: 1.05, 2.04) and 1.56 (95 percent CI: 1.13, 2.16), respectively) (table 2). Neither of these factors was associated with persistent wheezing. The use of a gas oven for cooking was not associated with either wheezing category. The presence of an electric storage heating system was associated with a lower risk of childhood wheezing (OR = 0.36, 95 percent CI: 0.14, 0.90) only.

Adolescent exposure. The use of any gas for cooking in adolescence (1996) was not associated with persistent or adolescent wheezing. However, risks of persistent wheezing were reduced with use of a gas hob for cooking and use of a gas hob fitted with an extractor fan for cooking (odds ratios were 0.67 (95 percent CI: 0.50, 0.91) and 0.70 (95 percent CI: 0.49, 0.99), respectively) (table 3). The use of a gas oven for cooking was again not associated with either wheezing category.

Smoking. Childhood exposure. Maternal smoking only (in 1987) was associated with an increased risk of persistent wheezing (OR = 2.10, 95 percent CI: 1.24, 3.55) (table 2). Smoking by both parents combined was associated with increased risks of childhood (OR = 1.78, 95 percent CI: 0.516 de Bilderling et al.
TABLE 2. Exposure to gas cooking and heating sources and cigarette smoking in childhood (1987), changes in exposure between childhood (1987) and adolescence (1996), and estimated risks of childhood and persistent wheezing in comparison with controls without exposure, Southampton, United Kingdom, 1987–1996

<table>
<thead>
<tr>
<th>Factor</th>
<th>Controls (%)&lt;br&gt;(n = 1,165)</th>
<th>Childhood wheezing (n = 196)</th>
<th>Persistent wheezing (n = 304)</th>
<th>ρ value (likelihood ratio test)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>% OR* &amp; 95% CI*</td>
<td>% OR &amp; 95% CI</td>
<td></td>
</tr>
<tr>
<td>Gender: female</td>
<td>48.2 44.3 0.84 0.61, 1.15</td>
<td>39.8 0.61 0.46, 0.81</td>
<td>≤0.01</td>
<td></td>
</tr>
<tr>
<td>Social class: manual</td>
<td>39.1 39.8 1.08 0.79, 1.48</td>
<td>38.2 0.99 0.74, 1.33</td>
<td>NS*</td>
<td></td>
</tr>
<tr>
<td>Atopic status: atopic</td>
<td>28.4 38.2 1.63 1.18, 2.24</td>
<td>83.9 14.77 10.43, 20.90</td>
<td>≤0.001</td>
<td></td>
</tr>
</tbody>
</table>

Exposure in childhood (1987)<sup>†</sup>

| Any gas for cooking | 56.9 67.3 1.47 1.05, 2.04 | 55.3 1.02 0.77, 1.36 | ≤0.05 |
| Gas hob for cooking | 47.6 58.6 1.56 1.13, 2.16 | 44.7 0.93 0.69, 1.26 | ≤0.05 |
| Gas hob + pilot light | 25.0 32.6 1.43 1.01, 2.02 | 24.3 1.02 0.72, 1.42 | NS |
| Gas oven for cooking | 39.3 44.3 1.16 0.85, 1.61 | 39.5 0.98 0.73, 1.33 | NS |
| Gas oven + pilot light | 25.5 30.6 1.17 0.82, 1.66 | 25.7 0.89 0.63, 1.24 | NS |
| Gas oven + fan | 5.2 6.1 1.21 0.63, 2.33 | 7.6 1.39 0.78, 2.46 | NS |
| Microwave cooking | 46.0 45.4 1.02 0.74, 1.39 | 46.0 1.09 0.81, 1.45 | NS |
| Gas central heating | 70.9 75.5 1.25 0.84, 1.87 | 71.7 1.10 0.77, 1.57 | NS |
| Electric storage heating | 7.0 2.5 0.36 0.14, 0.90 | 4.6 0.65 0.34, 1.24 | ≤0.05 |
| Gas fire for heating | 47.2 52.0 1.29 0.91, 1.81 | 52.3 1.36 0.97, 1.88 | NS |
| Only mother smoked | 7.8 7.6 1.18 0.64, 2.18 | 11.5 2.10 1.24, 3.55 | ≤0.05 |
| Only father smoked | 16.8 18.3 1.34 0.88, 2.04 | 15.9 1.16 0.77, 1.74 | NS |
| Both parents smoked | 11.8 17.3 1.78 1.14, 2.77 | 16.7 1.62 1.06, 2.46 | ≤0.01 |

Exposure in childhood (1987) and adolescence (1996)<sup>‡</sup>, <sup>‡</sup>

| Any gas for cooking | In 1987 only§ | 20.0 15.8 1.01 0.56, 1.81 | 23.3 1.12 0.70, 1.81 | ≤0.01 |
|                     | In 1987 and in 1996¶ | 36.3 49.5 1.76 1.05, 2.87 | 31.5 0.81 0.52, 1.26 | |
| Gas hob for cooking | In 1987 only | 19.4 15.8 1.13 0.65, 2.29 | 24.3 1.15 0.75, 1.78 | ≤0.001 |
|                     | In 1987 and in 1996 | 26.6 38.2 1.98 1.23, 3.18 | 19.4 0.62 0.40, 0.97 | |
| Gas hob with pilot light | In 1987 only | 18.2 20.9 1.36 0.89, 2.07 | 20.4 1.17 0.80, 1.72 | NS |
|                     | In 1987 and in 1996 | 5.6 9.6 2.13 1.19, 3.82 | 3.3 0.76 0.36, 1.62 | |
| Only mother smoked | In 1987 only | 2.3 0.5 0.01 0.00, 1.00 | 3.9 2.27 0.98, 5.27 | ≤0.001 |
|                     | In 1987 and in 1996 | 5.3 7.1 1.90 1.06, 3.39 | 6.3 2.18 1.15, 4.14 | |
| Only father smoked | In 1987 only | 6.1 5.6 1.20 0.61, 2.35 | 5.2 1.24 0.65, 2.36 | NS |
|                     | In 1987 and in 1996 | 10.4 12.7 1.47 0.90, 2.40 | 9.8 1.10 0.67, 1.80 | |
| Both parents smoked | In 1987 only | 2.2 3.1 1.57 0.63, 3.93 | 3.9 1.82 0.82, 4.06 | NS |
|                     | In 1987 and in 1996 | 6.3 9.1 1.85 1.03, 3.30 | 8.5 1.67 0.96, 2.92 | |

* OR, odds ratio; CI, confidence interval; NS, not significant (ρ > 0.05).
† In all analyses, results were mutually adjusted for the following confounding factors, defined a priori: atopy, gender, and social class (by paternal occupation: manual social classes (IIIb, IV, and V) vs. nonmanual social classes (I, II, and IIIa) (8)).
‡ Analyses were restricted to subjects with data from both childhood and adolescence and excluded those with missing values for either childhood or adolescence.
§ In 1987 only = present at age 7–8 years in the 1987 survey but not at age 15–17 years in the 1996 survey.
¶ In 1987 and in 1996 = present at both age 7–8 years in the 1987 survey and age 15–17 years in the 1996 survey.
TABLE 3. Exposure to gas cooking and heating sources and cigarette smoking in adolescence (1996), changes in exposure between childhood (1987) and adolescence (1996), and estimated risks of persistent and adolescent wheezing in comparison with controls without exposure, Southampton, United Kingdom, 1987–1996

<table>
<thead>
<tr>
<th>Factor</th>
<th>Controls (%) (n = 1,165)</th>
<th>Persistent wheezing (n = 304)</th>
<th>Adolescent wheezing (n = 203)</th>
<th>p value (likelihood ratio test)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>% OR*</td>
<td>95% CI*</td>
<td></td>
</tr>
<tr>
<td>Gender: female</td>
<td>48.2 39.8 0.62 0.46, 0.82</td>
<td>52.2 1.00 0.72, 1.39</td>
<td></td>
<td>≤0.01</td>
</tr>
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<td>Social class: manual</td>
<td>39.1 38.2 1.01 0.75, 1.36</td>
<td>52.2 1.76 1.26, 2.45</td>
<td></td>
<td>≤0.01</td>
</tr>
<tr>
<td>Atopic status: atopic</td>
<td>28.4 83.9 14.16 9.99, 20.09</td>
<td>73.9 7.11 4.99, 10.13</td>
<td></td>
<td>≤0.001</td>
</tr>
<tr>
<td>Ever smoking by adolescent</td>
<td>40.3 43.4 1.07 0.80, 1.44</td>
<td>40.9 1.00 0.71, 1.39</td>
<td></td>
<td>NS*</td>
</tr>
</tbody>
</table>

Exposure in adolescence (1996)

- Any gas for cooking 63.3 58.2 0.78 0.58, 1.06 62.6 1.06 0.74, 1.50 NS
- Gas hob for cooking 54.8 46.7 0.67 0.50, 0.91 55.7 1.07 0.76, 1.51 ≤0.05
- Gas hob + pilot light 20.9 17.8 0.93 0.64, 1.37 22.2 1.23 0.81, 1.85 NS
- Gas hob + fan 27.0 22.7 0.70 0.49, 0.99 32.5 1.28 0.89, 1.86 ≤0.05
- Gas oven for cooking 33.3 28.9 0.99 0.71, 1.38 32.0 1.66 0.98, 2.82 NS
- Gas oven + pilot light 16.1 14.5 0.93 0.62, 1.40 15.3 0.97 0.61, 1.53 NS
- Gas oven + fan 6.9 5.9 0.88 0.49, 1.59 7.90 1.32 0.71, 2.45 NS
- Microwave cooking 87.4 86.5 0.89 0.56, 1.40 90.6 1.30 0.73, 2.30 NS
- Gas central heating 84.4 81.6 0.63 0.41, 0.95 81.3 0.76 0.47, 1.23 NS
- Electric storage heating 4.5 1.4 1.40 0.76, 2.57 3.90 0.76 0.34, 1.71 NS
- Gas fire for heating 54.8 50.0 0.81 0.59, 1.10 52.7 0.97 0.67, 1.39 NS
- Only mother smoked 7.2 6.3 2.25 1.16, 4.36 6.4 1.63 0.78, 3.39 NS
- Only father smoked 10.4 9.8 1.13 0.68, 1.86 14.2 1.33 0.80, 2.23 NS
- Both parents smoked 6.3 8.5 1.62 0.91, 2.86 10.3 1.57 0.86, 2.85 ≤0.05

Exposure in childhood (1987) and adolescence (1996)

- Any gas for cooking
  - In 1987 and in 1996§ 36.3 31.5 0.73 0.47, 1.15 35.4 0.91 0.55, 1.51 NS
  - In 1996 only¶ 23.6 23.3 0.86 0.53, 1.38 21.1 0.82 0.47, 1.43
- Gas hob for cooking
  - In 1987 and in 1996 26.6 19.4 0.56 0.35, 0.99 29.5 1.13 0.68, 1.88 NS
  - In 1996 only 24.1 23.7 0.71 0.46, 1.11 21.1 0.88 0.52, 1.51
- Gas hob with pilot light
  - In 1987 and in 1996 5.5 3.3 0.62 0.28, 1.36 5.9 0.99 0.46, 2.17 NS
  - In 1996 only 12.8 11.5 1.00 0.62, 1.61 12.3 1.15 0.68, 1.93
- Only mother smoked
  - In 1987 and in 1996 5.3 6.3 2.25 1.16, 4.36 6.4 1.63 0.78, 3.39 NS
  - In 1996 only 0.2 1.3 4.07 0.66, 24.92 1.9 3.64 0.54, 24.39
- Only father smoked
  - In 1987 and in 1996 10.4 9.8 1.13 0.68, 1.86 14.2 1.33 0.80, 2.23 NS
  - In 1996 only 0.7 0.9 2.66 0.51, 13.79 0.5 1.15 0.13, 10.52
- Both parents smoked
  - In 1987 and in 1996 6.3 8.5 1.62 0.91, 2.86 10.3 1.57 0.86, 2.85 ≤0.05
  - In 1996 only 1.7 0 1.0 21.35 1.64, 278.47

* OR, odds ratio; CI, confidence interval; NS, not significant (p > 0.05).
† In all analyses, results were mutually adjusted for the following confounding factors, defined a priori: atopy, gender, and social class (by paternal occupation: manual social classes (IIIb, IV, and V) vs. nonmanual social classes (I, II, and IIIa) (8)), and personal history of smoking in adolescents. Data on risks related to personal smoking are given in table 4.
‡ Analyses were restricted to subjects with data from both childhood and adolescence and excluded those with missing values for either childhood or adolescence.
§ In 1987 and in 1996 = present at both age 7–8 years in the 1987 survey and age 15–17 years in the 1996 survey.
¶ In 1996 only = present at age 15–17 years in the 1996 survey but not at age 7–8 years in the 1987 survey.

**TABLE 4. Personal smoking habits of adolescent participants in 1996 and the relation of adolescent smoking to estimated risks of persistent and adolescent wheezing in comparison with controls without exposure, Southampton, United Kingdom, 1987–1996**

<table>
<thead>
<tr>
<th>Exposure in adolescence (1996)†</th>
<th>Controls (%) (n = 1,165)</th>
<th>Persistent wheezing (n = 304)</th>
<th>Adolescent wheezing (n = 203)</th>
<th>p value (likelihood ratio test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ever smoking by adolescent</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency of adolescent smoking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than once per week</td>
<td>10.6</td>
<td>12.5</td>
<td>1.17</td>
<td>0.75</td>
</tr>
<tr>
<td>At least once per week</td>
<td>5.9</td>
<td>7.2</td>
<td>1.35</td>
<td>0.76</td>
</tr>
<tr>
<td>Daily</td>
<td>5.4</td>
<td>6.6</td>
<td>1.40</td>
<td>0.75</td>
</tr>
</tbody>
</table>

* In all analyses, results were mutually adjusted for the following confounding factors, defined a priori: atopy, gender, and social class (by paternal occupation: manual social classes (IIIb, IV, and V) vs. nonmanual social classes (I, II, and IIIa) (8)).
† In adolescence (1996) = present at age 15–17 years in the 1996 survey but not at age 7–8 years in the 1987 survey.
‡ OR, odds ratio; CI, confidence interval; NS, not significant (p > 0.05).

1.14, 2.77) and persistent (OR = 1.62, 95 percent CI: 1.06, 2.46) wheezing. Paternal smoking only was not associated with any wheezing category in childhood or adolescence (tables 2 and 3).

Adolescent exposure. Maternal smoking only (in 1996) was again associated with an increased risk of persistent wheezing (OR = 2.06, 95 percent CI: 1.21, 3.50). Smoking by both parents combined was associated with an increased risk of adolescent wheezing (OR = 1.93, 95 percent CI: 1.10, 3.38) (table 3).

We also compared the subjects with no wheezing (controls; n = 1,165) with the “clearly persistent” (n = 205) and “indeterminate persistent” (n = 99) wheezing groups for exposures in childhood (1987) and adolescence (1996), similarly adjusting for gender, social class, and atopy in 1987 and for gender, social class, atopy, and active smoking in 1996. Associations previously identified in the analyses of combined persistent wheezing (n = 304) were again similarly identified; only the magnitude of the risks had changed (data not shown). There were no other significant differences or new associations, and the levels of risk were comparable for all other variables. We therefore concluded that the associations observed in the two strata of “clearly persistent” and “indeterminate persistent” wheezing were not substantively different, which supported our classification of persistent wheezing.

**Changes in childhood and adolescent exposure.** In these analyses, we compared different symptom groups in which a factor was either absent, present in childhood alone (in 1987 but not in 1996), present in both childhood and adolescence (in both 1987 and 1996), or present in adolescence alone (in 1996 but not in 1987). The risk of childhood wheezing was increased in subjects using any gas and any gas hob for cooking during both childhood and adolescence (odds ratios were 1.76 (95 percent CI: 1.05, 2.87) and 1.98 (95 percent CI: 1.23, 3.18), respectively) (table 2). The risk of persistent wheezing was reduced in subjects using any gas hob for cooking (OR = 0.62, 95 percent CI: 0.40, 0.97) during both childhood and adolescence (table 2).

Maternal smoking alone during both childhood and adolescence was associated with increased risks of childhood and persistent wheezing (odds ratios were 1.90 (95 percent CI: 1.06, 3.39) and 2.18 (95 percent CI: 1.15, 4.14), respectively). Paternal smoking alone in childhood and adolescence was not associated with any wheezing category (tables 2 and 3). The prevalence of new parental smoking in adolescence was low (1 percent across the symptom groups) but was associated with an increased risk of adolescent wheezing (OR = 21.35, 95 percent CI: 1.64, 278.47) (table 3).

The personal smoking habits of adolescents were not associated with the risk of persistent or adolescent wheezing in comparison with controls (table 4).

Analyses of crude prevalences of wheezing in symptom and control groups according to the duration of use of gas for cooking among families who had changed cooking fuel in the previous 15 years (compared with those who never used gas for cooking) showed a significantly lower prevalence of persistent wheezing among subjects who had used gas cooking fuel for 15 years or less (27.0 percent and 36.3 percent, respectively; p < 0.05) (table 5). The same comparison in families using gas cooking fuel for more than 15 years showed no difference in the prevalence of persistent wheezing in comparison with controls (41.1 percent vs. 37.3 percent; p value not significant). There were no differences in prevalence between controls and the other wheezing groups according to changes in the use of gas cooking fuel in the previous 15 years.

**DISCUSSION**

This study demonstrated associations between contemporaneous exposures to gas cooking and cigarette smoking and wheezing symptoms in children and adolescents. The use of any gas or a gas hob for cooking in childhood was associated with an increased risk of childhood wheezing, and the risk was higher among subjects who had been exposed in both childhood and adolescence. Exposure to gas cooking in adolescence was paradoxically associated with a reduced risk of persistent wheezing in subjects using a gas hob alone or a gas hob fitted with an extractor fan for cooking. There
were no significant associations with the use of gas heating or a gas oven for cooking. Maternal smoking was associated with persistent wheezing but also childhood wheezing if smoking had occurred throughout childhood and adolescence. Paternal smoking alone and the personal smoking habits of adolescents were not associated with any wheezing category. In contrast, combined smoking by both parents was consistently associated with all childhood, persistent, and adolescent wheezing groups.

This study allowed investigation of the effects of gas cooking, passive cigarette smoking, and exposure to other indoor pollutants on three different asthma phenotypes based on the presence or absence of wheezing symptoms in childhood and adolescence. It also allowed study of the effects of different types of gas cooking (including the use of gas hobs, pilot lights, and extractor fans) and the presence and duration of contemporaneous exposure on symptoms, and it included a sufficiently large group of adolescents to ensure adequate statistical power. In keeping with the limitations of most questionnaire surveys, we did not measure indoor pollutants directly, and the responses could have been prone to responder and recall bias for exposures in childhood.

We attempted to reduce recall and responder bias for both symptoms and risk factors. While the rates of response to the three surveys compared favorably with those of previous longitudinal studies of childhood respiratory disease, data were only available on 53 percent of the original cohort. However, the overall responder bias is likely to have been low, since the subjects’ parents had already answered two questionnaires (about 8 years apart) regarding their child’s respiratory symptoms and consistency between surveys was high (7). Repeated questionnaires may have reduced recall bias by this rehearsal effect. Cross-comparison of the data on symptoms and smoking confirmed that prevalences of the symptom groups were similar among respondents from the first two surveys and persons who did not reply to the third survey. To increase specificity, we asked about wheezing illnesses and not about cough. We also restricted the analyses to children who had more severe wheezing, defined as wheezy symptoms occurring every week. This reduced the size of the symptom groups (persistent = 203 and adolescent = 134), though the results were similar (data not shown). We also confirmed that nitrogen dioxide levels were significantly higher in the homes of adolescents reporting using gas for cooking compared with those using only electricity. We cannot conclusively evaluate how well the families recalled gas cooking exposure in childhood without prospective and detailed exposure records. Therefore, we cannot know definitively whether some families systematically over- or underreported exposure. Both would have been expected to add error to our measure of gas cooking exposure in childhood; in the end, we would expect them to have neutralized each other.

Studies of the use of gas cooking fuel and respiratory symptoms in children and adults show conflicting results (3, 9–11). While this inconsistency has been attributed to variable study power and misclassification of both exposure and health outcome (12), previous studies have not examined the influence of different gas cooking habits, the period of gas cooking exposure, behavior modification, the different effects on children and adolescents, and whether the inconsistency could be explained by severity of clinical disease or diversity of symptom groups (13). It is postulated that “transient-early” wheezing in infants and young children is related to viral infections, which may be more frequent in those with siblings and those attending day care (thereby increasing the opportunity to acquire viral infections) (14). We have recently shown that nitrogen dioxide exposure enhanced wheezing symptoms in children with upper respiratory system viral infections (5). It is therefore possible that the association between gas cooking and childhood wheezing could be due to interaction with cofactors such as infection rather than solely effects on wheezing. It is noteworthy that in subjects with childhood wheezing, 68 percent had wheezing earlier in childhood than during the previous 12 months at age 7–8 years. It is therefore possible that this group may contain a large proportion of subjects with virus-related wheezing illnesses. This may explain the lack of association between gas cooking exposure in childhood and persistent wheezing.

There is no clear biologic explanation as to why exposure to gas cooking increased the risk of childhood wheezing yet exposure to gas hobs for cooking reduced the risk of persistent wheezing. The reduced risk of persistent wheezing in adolescents from homes with a gas hob for cooking more likely reflects selective avoidance of gas hobs through behavior modification. We found that the prevalence of persistent wheezing was significantly lower among families who had changed their method of gas cooking in the

<table>
<thead>
<tr>
<th>Duration of use of gas for cooking</th>
<th>Controls (%; n = 1,165)</th>
<th>Childhood wheezing (%; n = 196)</th>
<th>Persistent wheezing (%; n = 304)</th>
<th>Adolescent wheezing (%; n = 203)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never used</td>
<td>19.2</td>
<td>15.8</td>
<td>21.4</td>
<td>18.7</td>
</tr>
<tr>
<td>≤15 years</td>
<td>36.3</td>
<td>38.3</td>
<td>27.0</td>
<td>≤0.05</td>
</tr>
<tr>
<td>&gt;15 years</td>
<td>37.3</td>
<td>40.8</td>
<td>41.1</td>
<td>39.4</td>
</tr>
</tbody>
</table>

* Analyses relate to the total numbers in each group, but weighted prevalences are given for brevity.
† NS, not significant (p > 0.05).
previous 15 years (and therefore during the lifetime of the adolescent) in comparison with families who never used gas for cooking (27.0 percent vs. 36.3 percent). Such a difference was not present in those adolescents with persistent wheezing whose families had used gas for cooking for more than 15 years. This difference in prevalence, whereby a change in gas cooking method was made, was observed at a threshold of 15 years, suggesting that the change or selective avoidance occurred in the lifetime of the adolescents with persistent wheeze and would have occurred during or after the onset of symptoms. This makes it possible that the avoidance of gas cooking (and presumably gas hobs) accounted for the reduced risk of persistent wheezing for exposures later in adolescence.

We previously described in part the associations between persistent and adolescent wheezing and exposure to cigarette smoke in our population (7). In this study, we have described the further role of active and passive smoking in all wheezing groups. Maternal smoking only was associated with persistent wheezing. Of more importance, the continued presence of indoor pollutant sources throughout the lifetime of some adolescents (compared with those for whom such exposures were absent or occurred only in childhood or adolescence) is important. We observed increased risks of childhood wheezing when only the mother smoked or any gas or gas hobs were used for cooking throughout both childhood and adolescence. These findings may reflect increased pollutant exposures due to different patterns or intensities of such habits between these groups. This suggests that children are more exposed to passive smoking when the mother smokes, since women with young families spend more time at home, and mothers who do not quit smoking are heavier smokers than those who quit or take up smoking later in life. Furthermore, combined parental smoking was associated with all three wheezing symptom groups and remained the most consistent risk factor for wheezing at any age. Therefore, there may be an additive effect of passive smoking when both parents smoke. In comparison, active adolescent smoking was not associated with any wheezing group, even when data were stratified by frequency of smoking.

This study did not demonstrate any significant effects of gas heating systems on risk of wheezing illness in any of the categories. The presence of an electric storage heating system in childhood was associated with a reduced risk of childhood wheezing, but the numbers were generally small. It is possible that this may represent a group of subjects less likely to use other forms of indoor heating and therefore pollutant sources.

We have demonstrated associations between different wheezing groups and exposure to domestic gas cooking and cigarette smoke. Children who experience wheezing only in childhood are most susceptible to the effects of gas cooking, but combined parental smoking is the most consistent risk factor for all wheezing illnesses. Reducing exposure to gas cooking in childhood and cigarette smoking in parents may provide treatment strategies for reducing wheezing illnesses in children and adolescents. The potential susceptibility of young children to the effects of gas cooking requires further research.

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The authors dedicate this study to the memory of their late friend, colleague, and coauthor, Jim Jeffs.

Conflict of interest: none declared.

REFERENCES

APPENDIX

The following are some of the questions asked in the 1996 and 1987 questionnaires.

Questions about the home

Questions about the house:
- whether the family had moved house
- when the home was built
- number of bedroom(s) in the house
- number of people sharing the young person’s bedroom
- sharing a bedroom with anyone who smokes cigarettes, cigars, or a pipe

Does his (her) bedroom have:
- carpets covering the whole floor
- double glazing
- upholstered or soft furnishings (such as cushions or sofas)
- soft toys (such as teddy bears)
- any windows
- any ventilation (e.g., a vent hole)?
- any window(s) in the following places (kitchen, bedroom, living room)

Questions about cooking

Do you use electricity for cooking at home? If yes,
- Does it have an extractor fan?

Do you use an electric oven? (excluding a microwave oven)
- Does it have an extractor fan?

How long have you used electricity for cooking?
- 0–5 years
- 6–10 years
- 11–15 years
- 16–20 years
- >20 years

Do you use a gas oven? If yes,
- Does it have a pilot light?
- Does it have an extractor fan?

How long have you used gas for cooking?
- 0–5 years
- 6–10 years
- 11–15 years
- 16–20 years
- >20 years

Do you have a microwave oven at home?

Do you use one of these appliances at home?
- Air conditioner(s)
- Dehumidifier(s)
- Air ionizer(s)
- Air filter(s)
- Extractor fan(s)

Questions about heating

Do you use the following types of heating at home?
- Gas central heating
- Electric storage heating
- Oil-fired central heating
- Solid fuel central heating
- Other electric fire(s) heater(s)
- Gas fire(s)
- Coal or wood fire(s)
- Paraffin heater(s)

Do you use any other types of heating at home?

The same questions about heating were administered as above but including the young person’s bedroom.

Questions about smoking

This concerned all people living in the household for at least 12 months, including the young person (adolescent).

In relation to the young person:

Do you currently smoke? If yes, how much: never, less than once per week, more than once per week, or daily?
- Does the father currently smoke?
- Does the mother currently smoke?
- Does the sibling currently smoke?