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The association of respiratory symptoms and lung function with the use of gas for cooking

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The association of respiratory symptoms and lung function with the use of gas for cooking. D. Jarvis, S. Chinn, J. Sterne, C. Luczynska, P. Burney on behalf of the European Community Respiratory Health Survey. ©ERS Journals Ltd 1998.

ABSTRACT: The association of respiratory symptoms and lung function with the use of gas for cooking was examined using data collected as part of the European Community Respiratory Health Survey, an international multicentre study.

Associations between gas cooking and respiratory symptoms and respiratory function were assessed by logistic and multiple regression models. Tests for interaction were used to examine whether the effect of gas cooking varied between centres and, as there was evidence for this, the average effects were estimated using standard methods for random effects meta-analysis.

Data from 5,561 males and 6,029 females living in 23 centres in 11 countries were analysed. There was no significant association found between respiratory symptoms and gas cooking in males. In females the association between some respiratory symptoms and gas cooking varied between centres with an overall positive association with "wheeze in the last 12 months" (odds ratio (OR) 1.24: 95% confidence interval (95% CI) 1.00–1.54) and "wheeze with breathlessness in the last 12 months" (OR 1.33: 95% CI 1.06–1.69). There was no evidence that atopy modified this association. Cooking with gas was associated with airways obstruction in both males and females although the differences failed to reach statistical significance.

In some countries the use of gas for cooking is associated with respiratory symptoms suggestive of airways obstruction in females.

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The domestic combustion of fossil fuels, especially the use of unvented gas appliances such as gas stoves, produces high indoor concentrations of several agents potentially harmful to health [1, 2]. Some [3–8] but not all [9, 10] studies have reported increased respiratory symptoms suggestive of either increased respiratory infection or asthma in children living in homes with gas cookers compared to those in homes with electric cookers. Few of these studies have reported significant loss of lung function [11] in exposed children. A case-control study in the UK showed no association between the presence of a gas cooker in the house and severe asthma in adolescents [12]. Studies in adults have not been conclusive. COMSTOCK *et al.* [13] reported an increased risk of respiratory symptoms in nonsmoking males living in homes with gas cookers. In a subsample [14] of this group gas cooking was associated with an increased risk of airway obstruction. Other studies in the USA have shown no association bet-ween gas cooking and symptoms in adults [15]. In Sin-gapore nonsmoking females who frequently used gas for cooking had more respiratory symptoms and worse lung function than females who used gas infrequently or not at all [16].

The European Community Respiratory Health Survey (ECRHS) has collected information on respiratory symptoms, lung function and the use of domestic gas appliances from representative samples of adults living in more than 30 centres, predominantly in Europe. An analysis of the data collected from three of the UK centres in East Anglia has shown a strong and consistent association between the use of gas cookers and respiratory symptoms in females but not in males [17]. Further analysis suggested that females sensitized to common environmental allergens may be at a greater risk of symptoms than nonatopic women, although formal statistical tests for effect modification by atopy failed to reach conventional levels of significance.

In this analysis we use data from all centres taking part in the ECRHS to examine whether there is an association between respiratory symptoms and lung function in adult females and if any such association is modified by atopy.

Methods

Data collection

The methodology for the ECRHS has been fully described elsewhere [18, 19]. Briefly, participating centres selected an area defined by pre-existing administrative boundaries with a population of at least 150,000. Where possible an up-to-date sampling frame was used to select randomly at least 1,500 males and 1,500 females aged 20–44 yrs. In stage 1 subjects were sent the ECRHS screening questionnaire, a self-completed nine-item questionnaire asking about symptoms suggestive of asthma, the use of medication for asthma and the presence of hay fever or nasal allergies. A random sample of subjects who completed the screening questionnaire were invited to attend a local test centre for completion of a more detailed interviewer-led questionnaire, blood tests for the measurement of specific immunoglobulin (Ig)E to house-dust mite, cat, timothy grass, *Cladosporium* and a common local allergen (Northern Europe: birch; Southern Europe: *Parietaria*; Australia, New Zealand and the USA: ragweed) and respiratory function testing.

Information was collected on fuels used for cooking (solid fuel, gas, electricity, paraffin *etc.*), the presence of a gas fire, the presence of a gas fired boiler, the presence and type of extractor fan above the stove (fumes removed to the outside of the home or not) and its use (always, some of the time, never), the year which the house was built (before 1981 or after 1981), type of home (flat or house), occupation (which was then coded into European Community Occupational Groups (ECOG)), smoking, and ex-posure to environmental tobacco smoke.

Serum samples were obtained by centrifugation of 10 mL whole blood at 4,000g for 10 min. All samples were stored at -20°C and analysed in a central laboratory by the CAP system (Pharmacia and Upjohn Uppsala, Sweden), except for samples from Melbourne which were analysed locally using the same method. The test for specific IgE was considered to be positive if a value greater than 0.35 $kU \cdot L^{-1}$ (the lowest detection limit of the assay) was obtained. Subjects were defined as atopic if they were positive to any one of the five allergens tested.

Forced expiratory volume in one second (FEV_1) and forced vital capacity (FVC) were measured with the participant seated and wearing a nose clip using either a spirometer or a pneumotach. Each participant was allowed a maximum of nine attempts to produce at least two technically satisfactory forced expiratory manoeuvres. FEV_1 and FVC values used in this analysis are from the curves with the highest FEV_1 reading.

Analysis

The prevalence of the use of gas and other fuels for cooking in each centre was determined.

In all further analyses males and females were considered separately. Only those who reported they used either a gas or an electric stove for cooking were included. Cen-

Table 1. – Response rates, total number of males and females in centres included in analysis, proportion using gas cookers and proportion having outside venting extractor fans

	Stage 2 n	Response %	Incl. in analysis*		Gas cooker %	With fan† %	Comment+
			Males	Females			
Sweden							
Goteborg	772	88	326	354	6.5	11.3	No natural gas, predominantly LPG if gas used
Germany							
Erfurt	1076	68	367	352	49.3	15.5	95% of all households supplied with natural
Hamburg	3312	38	629	618	11.9	16.1	gas#
Netherlands							
Bergen-op-zoom	638	71	178	198	85.5	88.8	100% of all households supplied with natural
Geleen	671	62	217	234	80.5	76.2	gas#
Groningen	599	63	189	192	95.5	36.2	
Ireland							
Dublin	599	76	217	216	51.2	22.5	Natural gas mainly used
UK							
Cambridge	527	53	120	155	58.5	21.8	90% of all households supplied with natural
Caerphilly	532	72	159	218	71.1	17.1	gas#
Ipswich	682	66	189	229	56.6	17.3	
Norwich	655	72	193	279	62.3	11.5	
Belgium							
Antwerp City	867	65	256	297	69.9	41.6	93% of all households supplied with natural
South Antwerp	800	70	227	327	45.6	71.8	gas#
France							
Bordeaux	2936	19	272	259	71.4	35.4	86% of all households supplied with natural
Grenoble	1165	41	254	214	83.7	20.9	gas#
Montpellier	3736	12	210	239	72.4	32.9	
Paris	3113	21	291	322	62.9	16.1	
Spain							
Galdakao	576	84	230	232	63.2	73.9	15–25% of all households supplied with
Huelva	478	57	134	136	82.9	40.1	natural gas large proportion of remaining
Oviedo	522	68	171	175	84.4	48.6	household use LPG wide variation across Spain
USA							
Portland	1604	45	320	345	12.6	60.4	Mostly natural gas, some use of LPG
Australia							
Melbourne	1644	41	174	207	84.5	62.1	Natural gas mainly used
New Zealand							
Wellington	741	65	238	231	17.3	33.3	Natural gas mainly used

*: those included in the analysis are those who either use gas or electric cookers and have provided smoking information. †: gas cooker users with outside venting extractor fans. +: these comments apply to the supply of gas at national level, local variations may exist; #: information provided by Groupe Europeen de Recherches Gazieres. Incl.: included; LPG: liquid petroleum gas.

tres that had either a very high or very low prevalence of the use of gas were excluded if at the 5% level of significance the power to detect a fivefold increased risk of symptoms in those using gas cookers was less than 50%, assuming the prevalence of symptoms in the unexposed group was less than 10%.

The odds ratios (ORs) for reporting symptoms in those who used a gas cooker compared to those who used an electric cooker were estimated using logistic regression adjusting for: age (20–24, 25–34, 35–44 yrs); smoking (lifetime nonsmoker, exsmoker, current smoker); and centre in which the study was conducted.

Lung function was expressed as FEV_1 as a percentage of predicted value (FEV_1 % pred) [20] and as observed FEV_1 expressed as a percentage of observed value (%FEV_1/FVC). Multiple regression was used to estimate their association with the use of a gas cooker with adjustment for age, centre and smoking.

Tests for interaction were used to examine whether the effect of gas cooking varied between centres. Because there was strong evidence that effects did vary the ORs were estimated separately (adjusting for age and smoking) in each centre and average effects derived using standard methods for random effects meta-analysis [21]. In some analyses there were insufficient data to include the centre as a random effect while adjusting for confounders. When this occurred ORs were estimated separately by country adjusting for: age; smoking; and centre within countries.

All analyses were conducted using the statistical package STATA (STATA Corporation, Texas, USA) [22].

Results

Data were obtained from 34 centres in 14 countries. Response to the request to attend the testing centre varied widely from as low as 12% in Montpellier (France) to above 80% in all Scandanivian centres.

In each centre at least 93% of the population used either gas or electricity for cooking. The following subjects were excluded from further analysis: 69 who cooked with a coal, coke or wood fire; 79 who cooked with another form of fuel; 70 for whom information on cooking fuel was missing; and 151 for whom information on smoking was not available or inconsistent.

The prevalence of the use of gas for cooking varied widely, from less than 5% in Reykjavik (Iceland), Bergen (Norway), Umeå and Uppsala (Sweden), Christchurch and Hawkes Bay (New Zealand) to more than 95% in Barcelona and Albacete (Spain) and Pavia, Turin and Verona (Italy). Exclusion of those centres which had less than 50% power to detect a fivefold increased risk of wheeze in those who used gas compared to those who used an electric cooker, left a sample of 11,590 (5,561 males, 6,029 females) from 23 centres in 11 countries (table 1) for analysis.

Respiratory symptoms

As reported previously [23] the prevalence of symptoms varied widely between centres. Table 2 shows average associations between gas cooking and respiratory symptoms in males and females controlling for age and smoking. In males there was no evidence of an association with gas cooking for any of the symptoms and no evidence of heterogeneity between centres. In females the association varied between centres and this variation was more marked for symptoms of wheeze and hay fever than for other symptoms.

The ORs for wheeze with breathlessness in each centre in females are shown in figure 1. While the overall meta-analysis showed a positive association between gas cooking and wheeze with breathlessness there was evidence of heterogeneity with a nonsignificant but negative association in the three non-European centres in Australia, the USA and New Zealand and in some of the European cen-

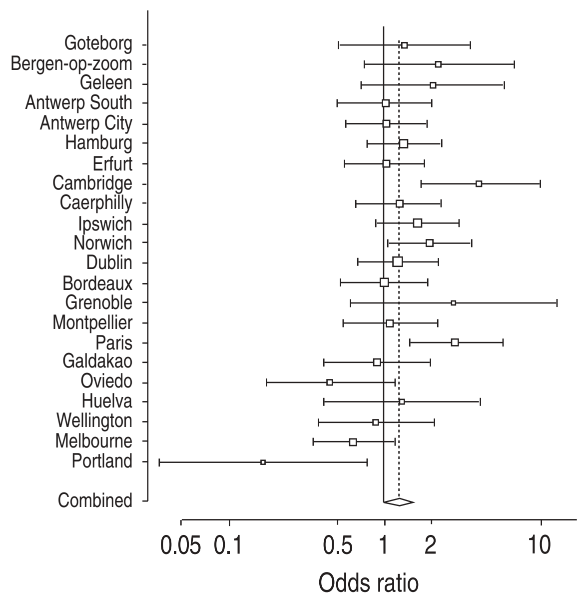

Fig. 1. – Adjusted odds ratios (ORs) (and 95% confidence intervals) of "wheeze with breathlessness in the last 12 months" with the use of gas cooking by centre in females (adjusted within centre for age and smoking) with combined ORs from the model with the centre as the random effect. The size of each square is proportional to the sample size.

Table 2. – Odds ratio (ORs) for gas cooking with symptoms in males and females

	Males n=5561		Females n=6026	
Symptoms in the last 12 months	OR* (95% CI)	Heterogeneity+	OR* (95% CI)	Heterogeneity+
Wheeze	1.04 (0.88–1.22)	p=0.4	1.24 (1.00–1.54)	p=0.021
Wheeze with breathlessness	0.94 (0.76–1.17)	p=0.3	1.33 (1.06–1.69)	p=0.1
Wheeze in the absence of a cold	1.03 (0.85–1.26)	p=0.3	1.31 (0.98–1.52)	p=0.003
Chest tightness	0.84 (0.69–1.02)	p=0.9	1.16 (0.98–1.39)	p=0.5
Waking with cough	1.06 (0.90–1.25)	p=0.9	1.09 (0.95–1.24)	p=0.6
Hayfever or nasal allergies	1.06 (0.90–1.25)	p=0.5	1.03 (0.87–1.25)	p=0.054

95% CI: 95% confidence interval. *: adjusting for: age; smoking and combined using random effects meta-analysis. +: test for heterogeneity between centres. "Waking with shortness of breath", "asthma attacks" and "current use of medication for asthma" not included because of the small numbers of affected individuals in some centres.

tres. For most of the other symptoms a similar geographical distribution was observed (positive associations in most of Europe and negative associations in Australia, New Zealand and the USA). The OR for gas cooking in each centre for "wheeze with breathlessness" in men are shown in figure 2.

The prevalence of "being woken with shortness of breath", "asthma attacks" and "current use of asthma medication" was too low in some centres to allow analyses within each centre, controlling for age and smoking. However for "waking with shortness of breath" prevalence was high enough for analysis by country. An association between gas cooking and waking with shortness of breath was observed in females (combined OR 1.34; 95% confidence interval (95% CI) 1.04–1.74) but not in males (combined OR 0.83; 95% CI 0.63–1.10) (figs. 3 and 4).

Adjustment for other confounders

Analyses were repeated, adjusting for further potential confounders including: exposure to environmental tobacco smoke; age of house; presence of gas-fired boiler; presence of an open gas fire; and presence of an extractor fan within each centre. The analysis was restricted to the 5,662 females and 5,316 males with complete data. In both males and females these further analyses did not greatly alter the association of symptoms of wheeze with cooking with gas and did not substantially explain the variation between centres in this association in women (OR for wheeze 1.22; 95% CI 0.95–1.56: test for heterogeneity p=0.02, OR for wheeze with breathlessness 1.32; 95% CI 1.02–1.69: test for heterogeneity p=0.2, OR for wheeze in the absence of a cold 1.36: 95% CI 0.99–1.87: test for heterogeneity p=0.01). Similarly, estimates were not altered by adjustment for ECOG.

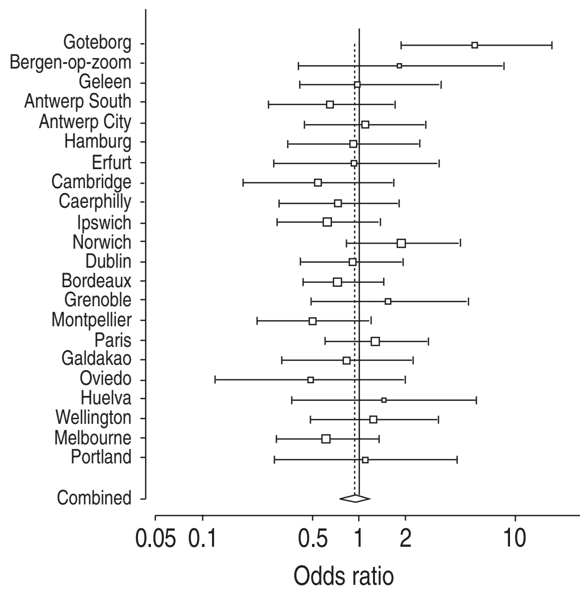

Fig. 2. – Adjusted odds ratios (ORs) (and 95% confidence intervals) of "wheeze with breathlessness in the last 12 months" with the use of gas cooking by centre in males (adjusted within centre for age and smoking) with combined OR from the model with the centre as the random effect.

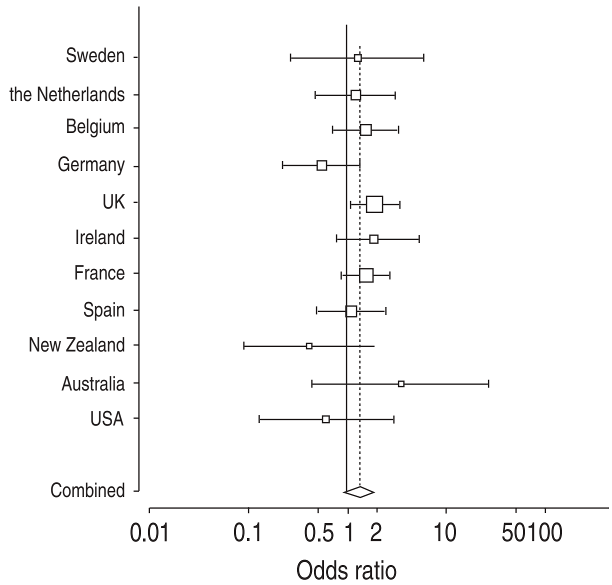

Fig. 3. – Adjusted odds ratios (ORs) (and 95% confidence interval) of "waking with attacks of shortness of breath in the last 12 months" with the use of gas cooking in females by centre (adjusted for age and smoking) with combined OR from the model with the country as the random effect. For definitions refer to figure 1.

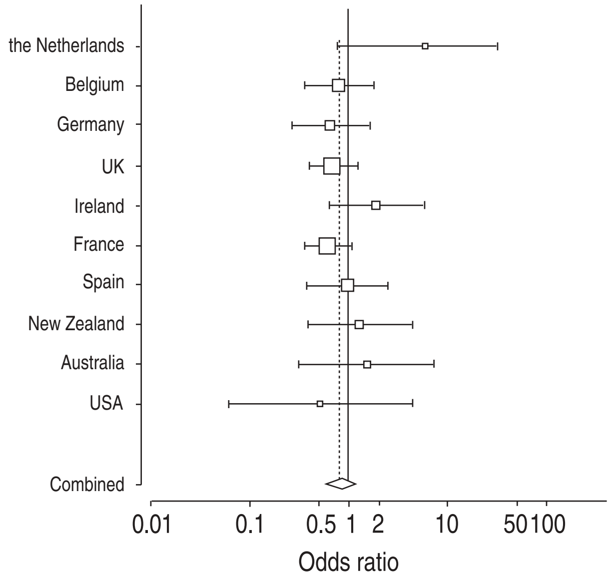

Fig. 4. – Adjusted odds ratio (ORs) (and 95% confidence interval) of "waking with attacks of shortness of breath in the last 12 months" with the use of gas for cooking by centre in males (adjusted for age and smoking) with combined OR from the model with the country as the random effect. For definitions refer to figure 1.

Effect modification by smoking

The analysis was stratified into nonsmokers (lifetime nonsmokers and exsmokers) and current smokers and data were analysed by country adjusting for age and centre in which the study was conducted. Nonsmoking females were at a greater risk of symptoms if they cooked with gas than females who smoked. This difference, however, did not reach conventional levels of significance (table 3).

Effect modification by atopy

Blood samples were obtained from 4,510/5,561 (81.1%) males and 4,439/6,029 (73.6%) females. The response

Table 3. – Odds ratio (ORs) for gas cooking with wheeze in nonsmoking and smoking males and females

Symptoms in the last 12 months	Nonsmokers OR* (95% CI)	Nonsmokers Heterogeneity+	Smokers OR* (95% CI)	Smokers Heterogeneity+
Females	(n=3998)		(n=2031)	
Wheeze	1.35 (1.05–1.66)	p=0.3	1.08 (0.76–1.53)	p=0.03
Wheeze with breathlessness	1.39 (1.05–1.87)	p=0.3	1.29 (0.92–1.74)	p=0.5
Wheeze in the absence of a cold	1.55 (1.09–2.08)	p=0.2	1.06 (0.76–1.48)	p=0.2
Males	(n=3343)		(n=2218)	
Wheeze	1.00 (0.79–1.25)	p=0.7	1.11 (0.89–1.39)	p=0.4
Wheeze with breathlessness	0.89 (0.67–1.19)	p=0.6	1.00 (0.70–1.44)	p=0.15
Wheeze in the absence of a cold	0.95 (0.72–1.25)	p=0.9	1.18 (0.81–1.58)	p=0.07

95% CI: 95% confidence interval. *: adjusting for age and centre and combined using a random effects meta-analysis. +: test for heterogeneity between countries.

Table 4. – Odds ratio (ORs) for gas cooking with wheeze in nonatopic and atopic males and females

Symptoms in the last 12 months	Nonatopic OR* (95% CI)	Nonatopic Heterogeneity+	Atopic OR* (95% CI)	Atopic Heterogeneity+
Females	(n=2927)		(n=1362)	
Wheeze	1.16 (0.88–1.52)	p=0.2	1.15 (0.85–1.53)	p=0.6
Wheeze with breathlessness	1.11 (0.78–1.58)	p=0.3	1.26 (0.89–1.75)	p=0.2
Wheeze in the absence of a cold	1.19 (0.86–1.66)	p=0.3	1.32 (0.93–1.88)	p=0.4
Males	(n=2614)		(n=1735)	
Wheeze	1.03 (0.72–1.48)	p=0.09	0.96 (0.75–1.23)	p=0.8
Wheeze with breathlessness	1.03 (0.72–1.47)	p=0.85	0.86 (0.64–1.15)	p=0.6
Wheeze in the absence of a cold	1.02 (0.74–1.39)	p=0.4	0.87 (0.64–1.17)	p=0.4

95% CI: 95% confidence interval. *: adjusting for: age group; smoking and centre and combined using a random effects meta-analysis. +: test for heterogeneity between countries (USA dropped from analysis due to small numbers of nonatopic subjects with electric cookers).

rate to venepuncture varied between centres, with all centres except Antwerp City (Belgium) achieving a response rate of more than 50% and six centres achieving response rates greater than 90%.

In this smaller sample, data were analysed by country adjusting for smoking, age and the centre in which the study had been conducted. Table 3 shows overall associations between gas cooking and symptoms of wheeze. Females who were atopic were at a greater risk of symptoms if they cooked with gas than females who were nonatopic. This difference, however, did not reach conventional levels of significance (table 4).

Respiratory function

Measurements of FEV_1 and FVC were obtained from 4,931/5,561 (88.7%) males and 4,978/6,029 (82.5%) of females. Response rates within centres varied from 59.9–99.8%.

In females there was no significant association between the use of a gas cooker and lung function (table 4). In some centres there was inconsistency between the association of reported symptoms with gas cooking and lung function and gas cooking. For example in three of the four French centres where a positive association between gas cooking and reported "wheeze with breathlessness in the last 12 months" was observed, gas cooking was associated with a better lung function (fig. 5).

In males there was a negative association between the use of gas for cooking and FEV_1 % pred in males who had gas cookers with significant heterogeneity between centres (table 5). There was no significant association between %FEV_1/FVC and gas cooking in males.

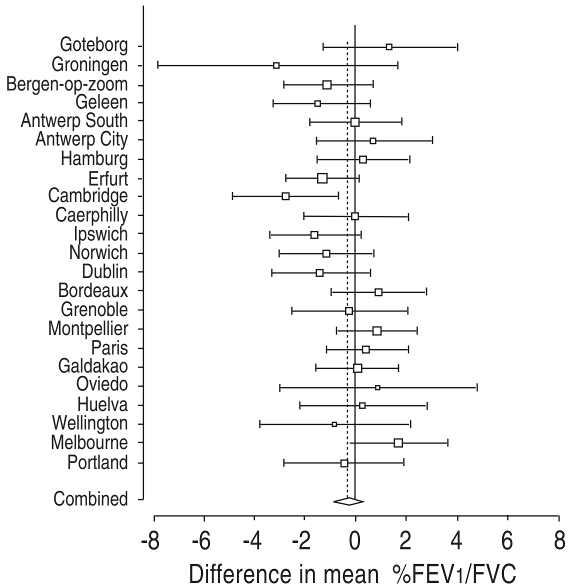

Fig. 5. – Difference (and 95% confidence interval) in mean percentage forced expiratory volume in one second (FEV_1)/forced vital capacity (FVC) in females cooking with gas and females cooking with electricity (value below 0 implies those with gas cookers have lower %FEV_1/FVC).

Extractor fans

The proportion of people who had an outside venting extractor fan in their kitchen varied widely between centres (table 1). Most people with outside venting extractor fans (86.9%) reported they used the fan whilst cooking some or all of the time. However there was no evidence that those with outside venting extractor fans had a lower

Table 5. – Regression coefficients of observed forced expiratory volume in one second (FEV_1) as FEV_1 % pred and % FEV_1/forced vital capacity (FVC) on gas cooking

	Males n=4931		Females n=4978	
	% change (95% CI)	Heterogeneity+	% change (95% CI)	Heterogeneity+
FEV_1 % pred	-1.12 (-2.23 to -0.01)	p=0.02	-0.46 (-1.43 to 0.51)	p=0.2
% FEV_1/FVC	-0.31 (-0.88 to 0.26)	p=0.2	-0.27 (-0.69 to 0.14)	p=0.2

95% CI: 95% confidence interval. *: adjusting for age and smoking and combined using a random effects meta-analysis. +: test for heterogeneity between centres.

risk of symptoms if they cooked with gas (in females: adjusted OR for wheeze with breathlessness in those with extractor fans 1.32; in those without extractor fans adjusted OR 1.35) even if they used the fans all of the time.

Discussion

We have previously reported a strong and consistent association between gas cooking and respiratory symptoms and decrement in lung function suggestive of asthma, in females, living in East Anglia [17]. The analysis presented in this paper has shown that the association between gas cooking, and symptoms and lung function is not consistently observed in all populations. In general, our results show a positive association between the use of a gas cooker and wheeze as reported by young adult females in most European centres and a negative association in Australia, New Zealand and the USA. However, in some centres objective assessment of lung function does not confirm these associations. In females, increased airways obstruction (reduced %FEV_1/FVC) in those using a gas cooker was observed in some countries in Europe (UK, the Netherlands, Ireland, Germany) but was also observed in New Zealand and the USA. In males, no consistent or significant association between gas cooking and symptoms was observed, although there was a statistically significant negative association between gas cooking and FEV_1 % pred.

The ECRHS is a large collaborative epidemiological study and study populations have been selected and surveyed using a standardized protocol. In view of published evidence that exposure to indoor gas appliances may influence respiratory health in children [3–5] information on the presence of gas cookers was collected. The project management group agreed a two stage plan for analysis. Firstly, data from individual centres within a country would be aggregated and analysed to examine potential risk factors for disease within the country. Assuming the analysis was accepted by the wider research community (*e.g.*, by publication in a peer reviewed journal), the analysis could then be repeated using the combined ECRHS data from all centres. This approach was developed to clarify the analysis plan and prevent false associations arising from multiple hypothesis testing based on the large combined ECRHS data set. Analysis of the UK data showing a strong and consistent association between gas cooking and symptoms and lung function in females but not males represented the first stage of this process [17]. The results presented here are the second stage. Independent analyses of data from the Belgian centres [24] and three of the four French centres [25] were performed following publication of the East Anglian analysis. These were conducted in a slightly different fashion to those described here, but the results were similar with the Belgian analysis showing no association between gas cooking and symptoms and the French analysis showing an association in females.

The key finding of these further analyses is the heterogeneity of the association between gas cooking and symptoms in females. As sample selection, exposure assessment and outcome assessment is standardized between centres we do not believe that differences in study design explain the heterogeneity. This leaves chance, confounding or effect modification as alternative explanations.

As with all statistical analyses it is possible that observations may have arisen by chance. There may be no true heterogeneity in the association between gas cooking and symptoms. The centres that have been included in this analysis may show greater variation between them than would be seen if the same analysis was conducted on a random sample of all possible centres.

In some centres, cooking with gas may be associated with some other environmental factor which in itself may be a risk factor for respiratory symptoms. This confounding may "create" false positive associations in some centres or "hide" true positive associations in others. Important potential confounders, including: age; smoking; exposure to environmental tobacco smoke; social class; the presence of a gas fire; the presence of a gas fired boiler; the age of the home; and the type of home, which have been considered in this analysis, do not fully explain the heterogeneity observed.

The effect of gas cooking on health may be modified by the presence of another factor, *e.g.* smoking or atopy. Tobacco smoke is an important source of nitrogen dioxide and total personal exposure to nitrogen dioxide in females who smoke may be only marginally increased by the use of gas for cooking. We have shown that if gas is used for cooking, females who do not smoke are at a slightly greater risk of symptoms than those who do smoke and use gas for cooking. However, even in this large sample the difference failed to reach conventional levels of statistical significance. Trials looking at changes in airway reactivity in response to inhalation of nitrogen dioxide and house-dust mite allergen support the hypothesis [26, 27] that atopy may also be an important effect modifier. As the prevalence of atopy varies widely between centres [28] it follows that variation in the risk of symptoms with gas cooking may also vary between centres. Although the analysis in East Anglia suggested that females with atopy may be at greater risk of symptoms with exposure to gas cooking than those who are nonatopic, in this analysis females (or males) with atopy did not have a substantially increased risk of symptoms if they used a gas cooker when compared to nonatopic females (or males). Variation in the association of wheeze with gas cooking between centres is not explained by variation in the prevalence of atopy in the different centres.

There are many by-products of gas combustion including water vapour, oxides of nitrogen, carbon monoxide and formaldehyde. Technical differences in the combustion process can alter the amount of nitrogen dioxide and carbon monoxide emitted, with levels of nitrogen dioxide and carbon monoxide being 75% lower when combustion is "clean" [29]. Therefore, the associations between the use of gas and health may vary with the type of gas, the temperature at which gas is burnt and the characteristics of the gas cooker itself. The term "gas" in this study includes natural gas (methane), bottled gas (liquid petroleum gas (LPG), containing varying mixtures of propane and butane), and "town gas" (methane produced by the combustion of coal). Even within these broad terms the precise composition of the gas mixture varies considerably between sources and emissions vary with the characteristics of the appliance used. Subjects taking part in the ECRHS were not asked which type of gas they used and we are, therefore, unable to determine whether the variation between centres can be explained by variation in the gas used. VIEGI *et al.* [30] in a survey of the general population in Northern Italy showed an increased prevalence of some respiratory symptoms in those who used bottled gas (propane) compared to those who used natural gas (methane) but the results are far from conclusive. At an ecological level using information provided by the Groupe Europeen de Recherches Gazieres (GERG) (table 1) both positive and negative associations were observed in centres predominantly using natural gas. The UK like many other participating centres in the ECRHS, has an extensive natural gas supply. However, unlike in the UK, in many other countries varying mixtures of tertiary butyl mercaptan, ethyl mercaptan, methylethyl sulphide and diethyl sulphide (instead of tetrahydrothiphenene) are used for adding smell to the gas (personal communication, GERG) are used.

The accumulation of by-products from gas cooking both in the home and around the cooker can be reduced by direct exhaust to the outside and improved general ventilation of the home. This could modify the association between gas cooking and symptoms. However, regular use of an outside venting extractor fan did not reduce the risk of symptoms. We have no other precise measures of household ventilation but in warm climates where doors and windows are open, and particularly if ambient outdoor nitrogen dioxide levels are low, homes with gas cookers will have much lower levels of nitrogen dioxide and other by-products of combustion than "tight" homes using gas cooking in more temperate regions. This may be an important cause of the variation in associations between centres, which this study does not have sufficient information to address. This could only be addressed by a study in which objective markers of indoor levels of by-products of gas combustion are measured.

Although in general the adjusted OR obtained for females were higher than those obtained for males, this was not consistent for all centres. The power to detect significant interactions between gender and exposure at centre level was low. If gas cooking is harmful to respiratory health and this effect is related to high levels of gas combustion products at the time of cooking, females who in many families do most of the cooking, would be the group most at risk. However, females may also be more susceptible to these products than males [31].

The association between gas cooking and lung function did not fully reflect the association observed between symptoms and gas cooking. Firstly a small but significant decrement in FEV_1 % pred was observed in males with gas cookers implying that males may have symptoms but do not fully report them. This should be interpreted with caution as FEV_1 % pred depends on the derivation of predicted FEV_1 and analysis of the ECRHS data (J. Roca, personal communication) show that these prediction equations do not reflect lung function in healthy adults in some populations in Europe. Secondly, in females, not all centres which showed a positive association between respiratory symptoms and gas cooking showed an increased risk of airways obstruction and *vice versa*. Notwithstanding, both subjective and objective markers of disease appear to be associated with gas cooking in the UK, Germany, the Netherlands and Ireland.

In conclusion we have shown that in some countries the use of gas for cooking is associated with respiratory symptoms suggestive of airways obstruction in females. This association is not consistently confirmed by objective markers of lung function. It is possible that the health effects of gas cooking are modified by the nature of the gas or some other factor as yet undetermined and further research should be aimed at identifying these factors. In the meantime it is prudent for the public to ensure that their exposure to the by-products of gas combustion are minimized by appropriate maintenance of gas appliances and good kitchen ventilation.

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