Gas cooking is associated with small reductions in lung function in children

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Abstract:

**Rationale:** Inconsistent effects of gas cooking on lung function have been reported. In a previous study from Austria, we demonstrated a significant though small reduction of lung function parameters in children living in homes with gas stoves. We used a larger international database to check if this finding can be generalized.

**Objectives:** To study the relative impact of cooking with gas on lung function parameters of primary school children in a wide range of geographical settings we analyzed flow and volume data of approx. 24,000 children (aged 6 to 12 years) from 9 countries in Europe and North America.

**Methods:** Exposure information had been obtained by comparable questionnaires and spirometry followed a protocol of ATS/ERS. Linear regressions were used, controlling for individual risk factors and study area. Heterogeneity between study-specific results and mean effects were estimated using meta-analytical tools.

**Results:** On average gas cooking reduced lung function parameters. Overall effects were small (-0.1 to 0.7%) and only significant for FVC and FEV1. There was some indication that allergic children are more affected by gas cooking.

**Conclusions:** Under current housing conditions, gas cooking is associated with only small reductions in lung function.

**Key words:** Indoor pollutants, Nitrogen dioxide, Respiratory Health, Spirometry
Introduction

Until now findings on lung function effects of gas cooking are still controversial. While Berkey et al. [1] and Ware et al. [2] mostly showed no effect others [3-5] found a reduced lung function notably mostly in girls. Ponsonby et al. [6, 7] reported stronger effects in sensitized children. Several studies found reduced respiratory health mostly measured by reported symptoms associated with gas stoves [8-13].

We recently published a study from Linz, Austria in which spirometric lung function parameters were reduced in children from households with gas stoves by 1.1 to 3.4 percent [14]. The Austrian data were part of the PATY project, a large data pooling study on indoor and outdoor environmental factors on respiratory health of children. In the framework of the PATY project, we published on the health impact of smoking in pregnancy and current passive smoking on the lung-function of school children [15], indoor moulde [16] and socio-economic status [17]. The Austrian results on gas cooking triggered the interest in the effects of gas cooking in the larger data set from all 9 countries. The aims of the current paper are to evaluate the associations between gas cooking and lung function in a large population of children (~24,000) and to assess whether this association depends on gender and atopic status.
Methods

Details of the PATY study have been described before [15]. Briefly, the analysis pooled data of approx. 24,000 children (aged 6 to 12 years) from 9 countries in Europe (Austria, Germany, The Netherlands, Poland, Hungary, Czech Republic, and Slovakia) and North America (US and Canada). Lung function testing was performed according to the protocol of ATS [18], except for minimum exhalation time of 6 s (not feasible for children) and except for the Dutch study which followed the protocol of ERS [19]. Prediction formulas were developed for each country separately, according to the same regression model. Because lung growth in the time period of interest is not linear the lung function variables were log-transformed. Log (age), log (weight), and sex X log (height) were included in all calculations as the most important predictors for the log lung function variables [14, 15, 20, 21]. With this model, the exponentials of the effect estimates of exposure can easily be interpreted as percentage differences.

Study results are presented for the “basic model” adjusted for age, weight, height, sex, seasonal trends (by adding a dummy for the 4 seasons), technician and/or instrument (if the study center used more than one) and study area (as a random effect), and for the “adjusted model” additionally adjusted for potential confounders, namely smoking in pregnancy (that was found to be the strongest “smoking” predictor of lung function by Moshammer et al. [15]), recent respiratory infections, current medication, maximal parental education, household crowding, unventilated gas/oil/kerosene heater, mold, birth order, and ‘ever had a pet’. These study specific effect estimates and their confidence intervals were entered into a meta-analysis, from which Forrest plots of the estimates, a mean estimate, and a measure and Cochran $\chi^2$ test of between-study heterogeneity were obtained. The study specific estimates are assumed to follow a random distribution about a mean, and the estimation of this mean and its confidence interval takes into
account both the variation in study-specific estimates and the uncertainty (due to sampling variability) related to each study-specific estimate [22].
Results

Of the 24,019 respondents included in the study 9,783 (40.73%) reported cooking with gas while in the households of 13,887 (57.82%) children solely electric stoves were used (table 1). For 349 children information on cooking was missing. Averaged over all study centers cooking with and without gas was fairly evenly distributed. But while a high percentage of households from the CESAR centers (Central European Study of Air Pollution and Respiratory Health; Poland, Hungary, Czech Republic and Slovakia [23]) and from The Netherlands cooked with gas this was only true for a minority from North America and Austria. The German households displayed a more balanced distribution.

In the basic model gas stoves reduced all lung function parameters between 0.1% (MEF25) and 0.8% (PEF). This reduction was significant for FEV$_1$ (0.7%) and FVC (0.6%) only. There was limited indication for heterogeneity between study centers for PEF and MEF75 (p for heterogeneity: 0.062 and 0.097, table 2, figure 1). For the other parameters, no indication for heterogeneity was found. After adjusting for recent respiratory infections, current smoking exposure, smoking during pregnancy, maximal parental education, mold, pet ownership, season, and geographical area (adjusted model) the effect estimates did not change much. Effect estimates remained small and mostly insignificant (table 2).

In a restricted data set without the Austrian results the effects on FVC and FEV1 remained significant. After the elimination of the Austrian data there was no longer any hint of heterogeneity. Exclusion of the data set from North America as the largest instead of the Austrian one did not lead to substantial changes in the effect estimates.

There was no statistically significant difference in the effect estimates when stratified by gender. For boys, the effect estimates for FVC and FEV1 were 0.6 % (95% CI -0.1 to 1.3) and 0.6 % (95% CI -0.1 - 1.4). For girls, the corresponding estimates were: 0.8 (-0.2 - 1.8) and 0.9 (-0.1 –
P for interaction was 0.96 and 0.89 respectively. For most of the other lung function parameters stronger (although still insignificant) effects were found in boys. Stratifying by atopic status indicated stronger effects regarding all lung function parameters in children “allergic to things inhaled” (figure 2). This question was not included in the German questionnaire. Therefore in this data set the question on hay-fever was used instead. Inclusion and exclusion of the German data set gave fairly similar results as did the basic and the adjusted model. There was no indication of heterogeneity (all p much larger than 0.1) nor were there differences in the point estimates between fixed and random model. Figure 2 depicts the basic model including the German data with fixed estimates. Also interaction (atopy X gas cooking) was studied and the p-value of the interaction factor (again basic model, including German data set, and fixed estimates) is indicated in figure 2.

Additionally similar models were run to look for effects of reported molds, household crowding and heating device (the confounders in the adjusted model) but no consistent effects were found. The effect of smoking was reported in a separate paper [15].
Discussion

Several studies found reduced respiratory health associated with gas stoves [3-13]. Nitrogen dioxide emitted from gas stoves and ovens can increase exposure especially in small kitchens with tight windows to concentrations above the threshold limit value (protecting workers) and well above ambient air quality standards (protecting the general public). As an irritant gas poorly soluble in water NO₂ reaches the peripheral airways and causes small airway dysfunction [27]. Other irritant gases emitted during burning of natural gas such as formaldehyde are water soluble and therefore affecting the upper airways. (Ultra-)fine particulate matter might also be involved in lung function impairments. Fine particulates from cooking are not associated with gas cooking in particular, but with all heating of foods. Thus NO₂ and / or other unmeasured components from gas use could lead to inflammatory responses in the air ways [28]. PEF and MEF75 indicate large airway dysfunction, but the variability is caused by effort and muscle strength. MEF50 and MEF25 are less effort dependent, but their reproducibility depends on the completeness of exspiration. MEF25 would be the best indicator for small airway dysfunction if reproducible. This international pooled data set does not strongly support the comparatively strong findings from Austria [14]. There was only limited evidence of heterogeneity in effect estimates between centers. But even upon removal of the Austrian data (that had the strongest effects but had only little weight in the overall estimate because of the few numbers of exposed children) point estimates remained consistent (small reduction in all lung function parameters with gas cooking, significantly so for FVC and FEV1).

Infrastructure for gas supply differs between cities and also within cities and other factors that could eventually influence lung function might also vary spatially. For example the gas distribution system in some countries is restricted to the densely populated areas that likely also differ by outdoor air pollution and socio-economic status. Although we controlled for socio-
economic status by means of parents' education and indeed this did not alter the effect estimates.

This proxy for socio-economic status might not have been sufficient. Outdoor air pollution from central fixed monitors would have been to crude a measure of spatial differences and thus was not included in the analysis. Study area was included as a random effect even in the basic model. But a “very basic” model (simple linear model without random effects, data not shown) gave practically the same effect estimates. Therefore neither residual confounding by area effects nor over-adjustment by the random effect model seems likely.

The gas source in most of the participating centers during the time of the study was natural gas only. Measurements showed that gas stoves and ovens were the main source of NO2, and not gas furnaces, because most households at the time of the study used remote heating already.

Ventilation was partly missing and partly unused (extractor hoods over stoves).

Cooking with gas can lead to substantially different exposures of children. Indeed size of the kitchen, ventilation rate, intensity and duration of cooking and the time children spent at home and especially in the kitchen when cooking is going on would all have a major influence on individual exposure. But information on these factors was missing. Only information about the current home environment was available. It is conceivable that mobility differed between study centers leading to different percentages of children that did not live in the same home in former years. If indeed early life exposure is more important for lung function development [15] this would lead to an unknown amount of exposure misclassification. On the other hand, Moran et al. [29] found no persistent effect of childhood exposure to gas cooking but reduced lung function in young adults with current exposure.

This is not the only study finding no strong evidence of gas cooking having an impact on lung function [8, 30]. Corbo et al. [4] reported an effect of gas cooking only in girls with high IgE.

Even the early Viennese study [13] that in fact triggered this investigation in the first place, found only an increase in symptoms (cough) but no effect on lung function. Two more recent Austrian
studies [31, 32] also failed to demonstrate an impact of gas cooking on lung function. At least in Austria the size of flats tend to increase and children do spend less time in the kitchen with their parent cooking. In former days children have played or even done their homework in the kitchen where their mother / father could supervise them.

Contrary to others [3-5] we observed no consistent differences in the point estimates between girls and boys. Maybe these differences were caused mostly by gender specific behaviours (girls spending more time at home and/or in the kitchen) and these behavioural differences might no longer be true. We did find some evidence that atopic children display a stronger effect from gas cooking as reported before [4, 6, 7] although the number of atopic children exposed to gas cooking was rather small. It is evident that interaction is not significant for any single lung function parameter. In spite of the fact that in all lung function parameters the effects of gas cooking is stronger in atopic children the confidence intervals of the effect of gas cooking are always much broader for the atopic children. This is mostly due to the fact that there are less atopic children. So at least in those countries with very unbalanced distribution between gas and electric cooking there is only limited power to detect any effect in atopic children. Nevertheless when children with respiratory allergies are living in “gas cooking” households care should be taken of sufficient ventilation during cooking especially when the children are present in the kitchen.

Conclusion

The current study indicates that under current conditions cooking with gas results in a small reduction of lung function, at least in the volume parameters (FVC and FEV1).

Acknowledgements
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References


### Table 1: Distribution of gas cooking, gender, age, and atopy within the participating study groups

<table>
<thead>
<tr>
<th>Study center</th>
<th>North America§</th>
<th>Austria</th>
<th>Germany</th>
<th>Netherlands</th>
<th>Poland</th>
<th>Hungary</th>
<th>Czech Republic</th>
<th>Slovakia</th>
<th>Total</th>
<th>Total %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abbreviation</td>
<td>NA AT DE NL PL HU CZ SK</td>
<td>NA AT DE NL PL HU CZ SK</td>
<td>NA AT DE NL PL HU CZ SK</td>
<td>NA AT DE NL PL HU CZ SK</td>
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<td>NA AT DE NL PL HU CZ SK</td>
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<tr>
<td>Gas cooking</td>
<td>Yes 3,139 (24.6%) 264 (9.1%) 781 (43.7%) 1,435 (82.7%) 1,349 (91.6%) 1,143 (70.9%) 746 (92.6%) 926 (95.5%) 9,783 40.73</td>
<td>No 9,490 (74.5%) 2,551 (88%) 960 (53.7%) 272 (15.7%) 106 (7.2%) 417 (25.9%) 47 (5.8%) 44 (4.5%) 13,887 57.82</td>
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<tr>
<td>Missing</td>
<td>108 83 47 28 17 53 13 0 349 1.45</td>
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<tr>
<td>% of boys</td>
<td>51.04 53.28 50.45 49.57 49.32 47.61 56.45 53.51</td>
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<tr>
<td>% age 6 – 8</td>
<td>- 86.75 19.57 10.32 - - - -</td>
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<tr>
<td>% age 9 &amp; 10</td>
<td>30.34 12.97 36.86 39.88 28.33 6.94 12.03 16.8</td>
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<tr>
<td>% age 11 &amp; 12</td>
<td>69.66 0.28 43.57 49.8 71.67 93.06 87.97 83.2</td>
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<tr>
<td>% with atopy</td>
<td>20.7 14.79 4.65* 15.64 14.27 12.69 19.44 13.96</td>
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<tr>
<td>Total</td>
<td>12,737 2,898 1,788 1,735 1,472 1,613 806 970 24,019 100</td>
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<tr>
<td>References</td>
<td>[20] [24] [25] [26]</td>
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§ Data from United States (18 communities, approx. 80% of the children) and Canada (6 communities) in one single file.
* For Germany no data were available for the question “allergic to things inhaled”. “Percentage of children with hay fever” is given instead.
<table>
<thead>
<tr>
<th></th>
<th>Basic model</th>
<th>Adjusted model</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>All data sets</td>
<td>without Austria</td>
</tr>
<tr>
<td><strong>FVC</strong></td>
<td>0.6 (0.2; 1.1)</td>
<td>0.5 (0.1; 0.8)</td>
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<tr>
<td>p-Heterogeneity</td>
<td>0.304</td>
<td>0.4016</td>
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<tr>
<td><strong>FEV₁</strong></td>
<td>0.7 (0.1; 1.2)</td>
<td>0.5 (0.1; 0.8)</td>
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<tr>
<td>p-Heterogeneity</td>
<td>0.214</td>
<td>0.484</td>
</tr>
<tr>
<td><strong>PEF</strong></td>
<td>0.8 (-0.2; 1.9)</td>
<td>0.6 (-0.4; 1.5)</td>
</tr>
<tr>
<td>p-Heterogeneity</td>
<td>0.062</td>
<td>0.188</td>
</tr>
<tr>
<td><strong>MMEF</strong></td>
<td>0.4 (-0.7; 1.4)</td>
<td>0.1 (-0.9; 1.1)</td>
</tr>
<tr>
<td>p-Heterogeneity</td>
<td>0.396</td>
<td>0.570</td>
</tr>
<tr>
<td><strong>MEF₂₅</strong></td>
<td>0.1 (-1.2; 1.5)</td>
<td>-0.1 (-1.5; 1.2)</td>
</tr>
<tr>
<td>p-Heterogeneity</td>
<td>0.411</td>
<td>0.436</td>
</tr>
<tr>
<td><strong>MEF₅₀</strong></td>
<td>0.7 (-0.3; 1.7)</td>
<td>0.4 (-0.6; 1.5)</td>
</tr>
<tr>
<td>p-Heterogeneity</td>
<td>0.437</td>
<td>0.680</td>
</tr>
<tr>
<td><strong>MEF₇₅</strong></td>
<td>0.3 (-1.6; 2.2)</td>
<td>-0.6 (-2.0; 0.8)</td>
</tr>
<tr>
<td>p-Heterogeneity</td>
<td>0.097</td>
<td>0.605</td>
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</table>

*(bold: p < 0.05)*

**Table 2:** Relative change (reduction in % and 95% CI) of the expected lung function outcome due to cooking with gas. Coefficient estimates are from the basic (i.e. only adjusted for age, sex, height, weight, technician and/or instrument, season, and study area) and from the adjusted model (i.e. also adjusted for the potential confounders recent respiratory infections, current smoking exposure, smoking during pregnancy, maximal parental education, mold, and pet ownership).
Figure 1: Effect estimates of gas cooking (basic model), as the ratio of lung function for children with versus without gas cooking. Vertical line indicates 'no effect'. Horizontal lines represent 95% confidence intervals. Diamond shapes indicate the positions, and confidence intervals, of the mean estimates. The x-axis depicts odds ratios. So 0.99 is equivalent to a 1% decrease.
Abbreviations for all figures: NA: North America, NL: Netherlands, AT: Austria, DE: Germany, PL: Poland, HU: Hungary, CZ: Czech Republic, SK: Slovakia
Figure 2: Effect estimates of gas cooking as the ratio of lung function for children with versus without gas cooking (basic model). Mean pooled estimates stratified by atopic status (1 = “allergic to things inhaled – yes”; 0 = “no”). The y-axis depicts odds ratios. So 0.99 is equivalent to a 1% decrease.