

ORIGINAL ARTICLE

Gas cooking, respiratory and allergic outcomes in the PIAMA birth cohort study

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ABSTRACT

Objectives Evidence for a relationship between gas cooking and childhood respiratory health is inconsistent and few longitudinal studies have been reported. Our aim was to examine the association between gas cooking and the development of respiratory and allergic outcomes longitudinally in a prospective birth cohort study.

Methods The Prevention and Incidence of Asthma and Mite Allergy birth cohort study followed children from birth (1996/1997) until age 8. Annual questionnaires were used to document respiratory and allergic symptoms. Allergic sensitisation and bronchial hyper-responsiveness (BHR) were measured at age 8 in subpopulations. A total of 3590 children were included in the present analysis. We used generalised estimating equations and discrete-time hazard models to study the overall and age-specific associations between exposure to gas cooking and the risk of developing respiratory illnesses. Sensitivity analyses of intermittent, always, current and early exposure to gas cooking were conducted.

Results Ever gas cooking exposure was associated with nasal symptoms (sneezing, runny/blocked nose without a cold) during the first 8 years of life (OR=1.32, 95% CI 1.09 to 1.59), but not with lower respiratory tract infections, eczema, allergic sensitisation and BHR. Associations with nasal symptoms were similar among children with intermittent, always, current and early exposure. Among girls only, prevalent asthma was associated with ever gas cooking (OR=1.97, 95% CI 1.05 to 3.72).

Conclusions Overall, our findings provide little evidence for an adverse effect of exposure to gas cooking on the development of asthma and allergies.

INTRODUCTION

Gas cooking is an important source of indoor nitrogen dioxide (NO₂) and other combustion products such as ultrafine particles¹ and nitrous acid (HONO).² Children spend as much as 80% of their time indoors,³ which may lead to high exposures to gas cooking fumes. High indoor NO₂ concentrations were found to be associated with adverse respiratory effects in children, including increased incidence of asthma and other respiratory diseases.^{4–5} However, the effect of exposure to indoor pollutants from gas cooking on childhood asthma, respiratory symptoms and allergy continues to be debated.⁵ Several studies^{6–11} reported positive associations between gas cooking and respiratory symptoms (such as wheezing, cough, nasal symptoms and atopic rhinitis) and

eczema in children, while other studies showed no effects.^{12–15} Most studies so far were cross-sectional; prospective birth cohort studies conducted in Europe^{16–17} and Canada¹⁸ have also examined the associations between gas cooking exposure and childhood respiratory diseases. However, analyses within most^{16–18} of the previous birth cohorts have been essentially cross-sectional; little evidence has been found to support an association between gas cooking exposure and asthma.

Due to the lack of prospective cohort studies assessing the health effects associated with exposure to gas cooking longitudinally, we currently know very little about the relevance of the timing of gas cooking exposure including different exposure patterns, and we also know little about differences in susceptibility by age during childhood.

We used follow-up data from our prospective Prevention and Incidence of Asthma and Mite Allergy (PIAMA) birth cohort study to investigate the association between long-term residential exposure to gas cooking and development of respiratory symptoms and sensitisation over the first 8 years of life and to prospectively explore the possible relationship between (changes in) gas cooking habits and the development of respiratory and allergic symptoms.

MATERIALS AND METHODS

Study design

The PIAMA study is a prospective birth cohort study that started with 3963 newborns.¹⁹ Women were recruited in 1996–1997 during their second trimester of pregnancy from a series of communities in the north, west and centre of the Netherlands. Non-allergic pregnant women were invited to participate in a 'Natural History' Study (NHS). Allergic pregnant women were primarily allocated to a randomised double-blind intervention study assessing the effect of mite-impermeable mattress covers with a random subset allocated to the NHS.¹⁹ Since no effect of the intervention on the development of asthma and allergies was found,²⁰ participants of both the intervention study and the natural history study were included in the present analysis.

Parents completed postnatal questionnaires on demographic characteristics, symptoms related to respiratory illness and allergic diseases, diet and other risk factors including gas cooking when their child was approximately 3 months old and then yearly until age 8 years around the child's birthday. In addition, the participants' residential history was

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recorded during the follow-up. The study was approved by the Medical Ethical Committees of the participating institutions, and written informed consent was obtained from all participants.

Exposure assessment

Data of whether participants used gas for cooking were available in the 3-month questionnaire and yearly questionnaires until age 5. We assumed that the family would not change the cooking appliance if they did not move to another house. Therefore, for each participant, intermittent missing data of gas cooking at ages 1–5 years were assigned the same values as its neighbouring observations if the participant did not move between these two study periods.

Based on this information, two groups of gas cooking exposure were defined as never and ever exposure.

1. *Never gas cooking*: negative answers to the question about use of gas for cooking at all ages from 3 months to 5 years.
2. *Ever gas cooking*: at least one positive answer to the question about use of gas for cooking at ages 3 months to 5 years. We further subdivided ever exposure into two subgroups of (2a) always exposure: defined as positive answers to the question about use of gas for cooking at all ages from 3 months to 5 years and (2b) intermittent exposure: at least one positive and at least one negative answer to the question about the use of gas for cooking at ages 3 months to 5 years. The frequency distribution of cumulative exposure to gas cooking is presented in online supplementary figure E1; groups with 1–5 time points with exposure were too small to relate it to health outcomes. Therefore, we could not further subdivide the 'intermittent exposure' group.

To explore the relevance of the timing and duration of exposure, we defined the following additional exposure variables:

1. *Early exposure*: a positive answer to the question about use of gas for cooking at age 1 year.
2. *Current exposure*: exposure to gas cooking during the past 12 months at ages 1–8 years (time varying); information about exposure until the age of 5 years was available from questionnaires, current exposure from ages 6 years onwards was defined as exposure at age 5 years for those who did not move and defined as missing for those who did move to another house.
3. Number of questionnaires (ranging from 1–6) with reports of gas cooking exposure as a measure of cumulative exposure.

Health outcomes

Information about respiratory and allergic diseases was obtained from yearly questionnaires until age 8 years. The following health outcomes were defined as in previous analyses:²¹

1. *Prevalent asthma*: asthma ever diagnosed by a doctor and asthma during the past 12 months.
2. *Incident asthma* was defined as 'yes' the first time the question 'Did a doctor ever diagnose asthma in your child?' was positively answered. Incident asthma was defined as 'no' if the question on doctor diagnosed asthma was answered negatively in the respective year and all previous years.
3. *Wheeze*: at least one episode of wheezing during the past 12 months. Wheezing phenotypes: early transient wheeze was defined as wheeze during the first 3 years of life and not at ages 6, 7 or 8 years; late-onset wheeze was defined

as no wheeze during the first 3 years but wheeze at ages 6, 7 or 8 years; and persistent wheeze was defined as wheeze during the first 3 years and wheeze at ages 6, 7 or 8 years.

4. *Asthma symptoms*: at least one attack of wheeze or shortness of breath or the prescription of inhalation corticosteroids in the last 12 months.
5. *Lower respiratory tract infection (LRTI)*: parental report of a doctor's diagnosis of pneumonia or bronchitis.
6. *Hay fever*: responses of 'yes' to the question 'Has your child ever had hay fever'.
7. *Nasal symptoms*: sneezing or having a runny or blocked nose accompanied by itchy, watering eyes without having a cold in the past 12 months.
8. *Atopic eczema*: an itchy rash in the folds of the elbows or behind the knees or in front of the ankles or around the ears or eyes which was coming and going during the past 12 months.

At age 8, blood samples were collected for immunoglobulin E (IgE) determination in children who gave consent, and bronchial hyper responsiveness (BHR) was measured in all children of allergic mothers and a random selection of children of non-allergic mothers. More details are provided in the online supplementary material. Allergic sensitisation was defined as a positive reaction (IgE level >0.35 IU/ml) to one of the allergens tested; allergic sensitisation to pollen was defined as a positive reaction to cocksfoot (*Dactylis glomerata*) and/or birch pollen.

Statistical methods

χ^2 Tests were used to test for differences in characteristics between groups of children who were ever and never exposed to gas cooking.

We used generalised estimating equations²² with a logit link and an autoregressive correlation structure of order 1 to evaluate associations between gas cooking and repeated measures of health outcomes during the first 8 years of life. The correlation structure was selected by the Quasi-likelihood information criterion.²³ Associations between gas cooking and the incidence of asthma were analysed by means of a discrete-time hazard model.²⁴ Both age-specific and overall associations from the models with and without exposure–age interaction terms, respectively, were reported. Cross-sectional associations of allergic sensitisation and BHR with gas cooking were analysed by logistic regression and association between gas cooking and phenotypes of childhood wheezing by polytomous logistic regressions. Sensitivity analyses were performed examining the effect of current and early exposure, and relocation (more details provided in the online supplementary material). Furthermore, potential effect modification by gender or allergic status was tested in models with gas cooking–gender or gas cooking–allergic sensitisation interaction terms. All associations were reported as OR with unexposed children as the reference category with and without adjustment for potential confounding variables such as gender, maternal education, parental history of allergies, study arm, study region, breastfeeding, older siblings, day-care attendance during the first year of life, smoking, dampness and pets in the child's home as in previous analyses within the same cohort.^{16 21}

Statistical analyses were conducted with STATA 10 (V.10; StataCorp LP, College Station, Texas, USA).

RESULTS

General characteristics

After excluding participants who were lost to follow-up during the first 5 years (n=337) and participants with incomplete data on gas cooking (n=36), 3590 participants were eligible for the

present analysis. The follow-up period was 8 years. Of the 3590 participants, 483 were never exposed to gas cooking and 3107 were exposed at least once until age 5 years (table 1). From 3 months through 5 years, there was relatively little year-to-year variation in the percentage of children with gas cooking exposure (see online supplementary figure E2). Among those who were exposed, 472 (15.2%) had intermittent exposure and 2635 (84.8%) had persistent exposure.

Comparisons of baseline characteristics among participants who were never and ever exposed to gas cooking showed differences regarding gender, maternal education and study region ($p<0.05$).

Frequency distribution of health outcomes in relation to ever gas cooking

Prevalence of wheezing phenotype, BHR and allergic sensitisation which were observed only at age 8 are presented in table 1. χ^2 Tests did not reveal significant differences in the prevalence among 'never', 'intermittent' and 'always' exposure subgroups.

Figure 1 shows the age-specific frequency distribution of various health outcomes from age 1 or 3 to age 8 years. Frequencies of prevalent and incident asthma, wheeze, asthma symptoms, LRTIs and nasal symptoms in the past 12 months decreased with age. The annual percentage of children with reports of nasal symptoms ranged from 15.7% to 31.8% and was higher than that of the other health outcomes. The prevalence of atopic eczema was relatively stable over the years (13.2%–21.0%). Differences of the frequency distribution of these reported symptoms among 'never', 'intermittent' and 'always' exposure subgroups were small. However, 'intermittent' group had the most frequently reported hay fever, while the 'never' group had the lowest prevalence rate of nasal symptoms over the follow-up years.

Association of gas cooking exposure with health outcomes

Crude and adjusted associations between gas cooking exposure and health outcomes during the first 8 years of life are presented in the online supplementary figure E3 (see online supplementary

Table 1 Characteristics of participants included in the analysis, according to gas cooking category

Covariates, n (%)	All study participants (N=3590)	Never gas cooking (N=483)	Ever gas cooking (N=3107)	Ever gas cooking	
				Intermittent exposure (N=472)	Always exposure (N=2635)
Boy*	1866 (52.0)	280 (58.0)	1586 (51.1)	227 (48.1)	1359 (51.6)
Study arms					
Intervention	634 (17.7)	89 (18.4)	545 (17.5)	96 (20.3)	449 (17.0)
Natural History	2956 (82.3)	394 (81.6)	2562 (82.5)	376 (79.7)	2186 (83.0)
Atopic mother	1048 (29.2)	145 (30.0)	903 (29.1)	142 (30.1)	761 (28.9)
Atopic father	1102 (30.7)	151 (31.3)	951 (30.6)	151 (32.0)	800 (30.4)
Mother education†*					
Low	797 (22.4)	113 (23.6)	684 (22.2)	106 (22.5)	578 (22.1)
Intermediate	1503 (42.1)	230 (48.0)	1273 (41.2)	204 (43.2)	1069 (40.9)
High	1264 (35.5)	136 (28.4)	1128 (36.6)	162 (34.3)	966 (37.0)
Dampness‡	286 (8.3)	32 (6.9)	254 (8.5)	23 (5.1)	231 (9.1)
Older siblings at birth	1801 (50.2)	250 (51.8)	1551 (49.9)	207 (43.9)	1344 (51.0)
Smoking at home‡	964 (27.0)	112 (23.3)	852 (27.6)	109 (23.1)	743 (28.4)
Any pets at home‡	1775 (49.6)	220 (45.6)	1555 (50.2)	220 (46.6)	1335 (50.9)
Breastfeeding§	1587 (44.7)	194 (40.8)	1393 (45.3)	208 (44.5)	1185 (45.4)
Day-care‡	2008 (56.5)	266 (55.6)	1742 (56.6)	286 (60.9)	1456 (55.8)
Study region*					
North	1133 (31.6)	101 (20.9)	1032 (33.2)	111 (23.5)	921 (35.0)
Middle	1475 (41.1)	214 (44.3)	1261 (40.6)	199 (42.2)	1062 (40.3)
West	982 (27.3)	168 (34.8)	814 (26.2)	162 (34.3)	652 (24.7)
Relocation (age 6–8)	663 (18.5)	68 (14.1)	595 (19.2)	102 (21.6)	493 (18.7)
Wheezing phenotype					
Never	2158 (61.8)	278 (59.8)	1880 (62.1)	267 (58.2)	1613 (62.8)
Early transient	876 (25.1)	127 (27.3)	749 (24.8)	128 (27.9)	621 (24.2)
Late onset	145 (4.2)	23 (4.9)	122 (4.0)	20 (4.3)	102 (4.0)
Persistent	312 (8.9)	37 (8.0)	275 (9.1)	44 (9.6)	231 (9.0)
Allergic sensitisation¶					
Any allergen positive	686 (40.6)	92 (36.7)	594 (41.3)	90 (40.4)	504 (41.5)
Inhalant allergens	542 (32.1)	72 (28.7)	470 (32.6)	70 (31.3)	400 (32.9)
Grass and/or birch pollen	266 (15.8)	33 (13.2)	233 (16.2)	42 (18.8)	191 (15.7)
Food allergens	284 (16.8)	41 (16.3)	243 (16.9)	38 (17.0)	205 (16.9)
BHR**	399 (43.0)	51 (40.8)	348 (43.3)	64 (49.6)	284 (42.1)

*Significant difference between never and ever gas cooking subgroups, $p<0.05$.

†Low: primary school, lower vocational or lower secondary education; intermediate: intermediate vocational education or intermediate/higher secondary education; high: higher vocational education and university.

‡During the child's first year of life.

§For at least 3 months.

¶N=1699.

**Bronchial hyper responsiveness, N=929.

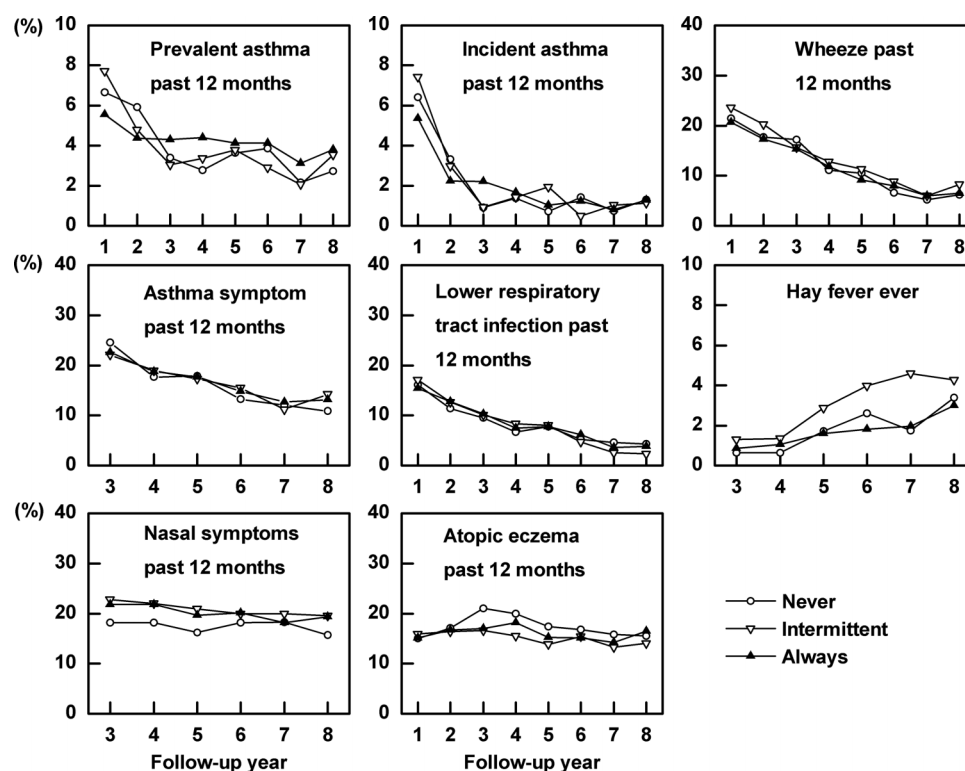


Figure 1 Frequency distribution of health outcomes by age.

material) and figure 2, respectively. The adjusted OR is not much different from the crude OR in overall and age-specific analyses. The overall adjusted associations between health outcomes measured repeatedly and ever gas cooking exposure were positive for all health outcomes except atopic eczema, and most clear for nasal symptoms only (figure 2). Including gas cooking-age interaction terms into the longitudinal models, elevated OR of prevalent and incident asthma was seen in children starting at age 3, whereas little variation of the effects of gas cooking on other health outcomes was seen with age. Similar to the overall effects, no associations were found in age-specific effects with the exception of nasal symptoms at ages 4, 5 and 8 years. When exposed children were subdivided by different exposure pattern ('intermittent' and 'always'), the two subgroups were found to have very similar risks (figure 2). For some outcomes (eg, wheeze and hay fever), the risk tended to be the highest in children with intermittent exposure, but differences between intermittent and always exposure were generally small.

Associations between wheezing phenotypes and health outcomes tested at the age of 8 only are presented in table 2. Ever gas cooking exposure was positively associated with allergic sensitisation and BHR, but not with wheezing phenotypes. Intermittent, but not always exposure, was associated with an elevated risk of BHR (OR 1.65, 95% CI 0.94 to 2.89, $p < 0.10$). When analyses for prevalent and incident asthma were performed separately in children aged 4 years and older, where a more reliable diagnosis of asthma is possible, ORs were higher.

Sensitivity analyses

The associations between gas cooking exposure and the health outcomes remained generally consistent with those of ever exposure in a variety of additional analyses, as shown for early and current exposure in table 2. For example, early and current exposure were positively associated with nasal symptoms

(OR=1.17, 95% CI 1.00 to 1.37 and OR=1.22, 95% CI 1.06 to 1.41, respectively). Estimated effects of early and current exposure revealed little variation on incident asthma, wheeze, asthma symptoms, LRTI, nasal symptoms, atopic eczema and wheeze phenotypes. However, across the three exposure patterns, the effect on prevalent asthma was most pronounced for the children with current exposure to gas cooking; the OR was 1.19 (95% CI 0.86 to 1.65) for ever exposure and 1.29 (95% CI 0.98 to 1.69) for current exposure to gas cooking. Defining 'early exposure' as a positive answer to the question on use of gas for cooking at age 1 and/or 2 years instead of age 1 year only did not change our findings (data not shown).

Since we categorised the gas cooking exposure groups based on information until age 5, we were concerned whether changes in residential address between ages 6 and 8 years would have introduced some bias. We therefore repeated all analyses without the 663 children who changed address between 6 and 8 years of age. Results remained basically unchanged. Moreover, we excluded 1904 families who reported home renovation during the first 5 years and found that it made no difference to the findings (data not shown).

Effect modification by gender or allergic status

We investigated the associations of health outcomes with gas cooking exposure for boys and girls separately by including exposure-gender interaction terms in the models (table 3). The relation between ever gas cooking exposure and prevalent asthma, incident asthma, allergic sensitisation to food allergens and BHR was noticeably larger in girls than in boys, although the gender-related difference was not significant. Prevalent asthma was independently associated with ever gas cooking in girls (OR=1.97, 95% CI 1.05 to 3.72), but not in boys. The associations of ever gas cooking exposure with hay fever and persistent wheeze were somewhat larger in boys than in girls.

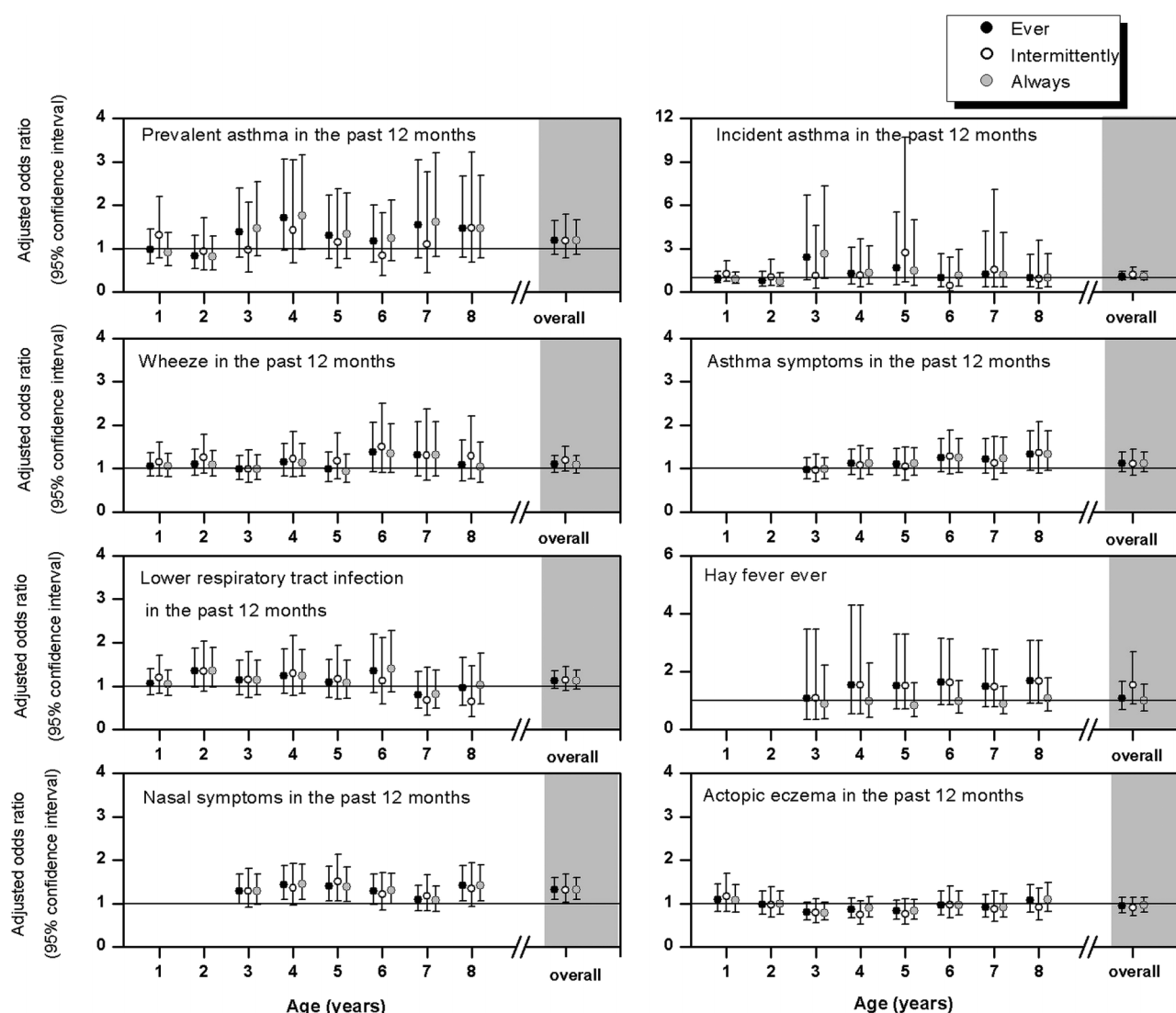


Figure 2 Adjusted age-specific and overall association among ever, intermittent and always exposure to gas cooking and health outcomes during the first 8 years of child's life. Results are presented as adjusted OR with 95% CI. ORs were adjusted for gender, maternal education, parental history of atopy, study arm, study region, breastfeeding, presence of older siblings, environmental tobacco exposure in the home, signs of dampness in living room and the child's bedroom, pets in the child's homes, day-care attendance in the first year of life and relocation during first 8 years of life.

Moreover, we explored the impact of allergic status by including terms for the interaction between gas cooking and allergic sensitisation to inhalant allergens in the model. Although the results indicated stronger effects on prevalent asthma, LRTI, hay fever and nasal symptoms in children with allergic sensitisation, these differences did not reach significance ($p > 0.05$).

DISCUSSION

Our results provided some evidence for an increased risk of nasal symptoms related to gas cooking exposure. Other symptoms and outcomes were not associated although in gender or allergy status stratified analyses, there seemed to be an association between gas cooking and prevalent asthma among girls.

We previously reported an association between gas cooking exposure at age 5 and nasal symptoms at age 4, using cross-sectional data.¹⁶ The present results, using longitudinal data from ages 1–8 years, show that the association with nasal symptoms persisted until age 8. In the previous study, an exposure model was used including kitchen ventilation, kitchen volume

and other gas combustion source data that were uniquely collected at age 5 to minimise exposure misclassification. It was found that in our population, taking kitchen characteristics into account did not lead to different conclusions than the simple comparison of gas cooking versus using electricity for cooking. The present study was built on those earlier findings, and therefore did not consider kitchen characteristics.

Nasal symptoms are a sign of rhinitis, which in itself is associated with asthma and frequent hospital visits.²⁵ In our study, nasal symptoms, which we defined by sneezing and runny/blocked nose without a cold, are associated with ever gas cooking exposure. An increased risk of nasal symptoms in children with exposure to gas cooking has also been found in other studies.^{26–27} In our analysis, different classifications of gas cooking exposure were used. The advantage of this classification is the possibility to make a distinction between different gas cooking behaviours. When considering the gas cooking exposure by frequency (intermittent and always exposure) and by period (early and current exposure), the effects on nasal symptoms

Table 2 Adjusted associations between respiratory health outcomes and ever, current and early gas cooking exposure

Health outcomes	Early versus never gas cooking OR* (95% CI)	Ever versus never gas cooking OR* (95% CI)	Current versus never gas cooking OR* (95% CI)
During the first 8 years†			
Prevalent asthma‡			
before age 4 only	1.00 (0.73 to 1.35)	1.01 (0.71 to 1.43)	1.03 (0.76 to 1.41)
after age 4 only	1.40 (0.96 to 2.03)	1.43 (0.93 to 2.22)	1.56 (1.09 to 2.25)
all ages	1.15 (0.87 to 1.52)	1.19 (0.86 to 1.65)	1.29 (0.98 to 1.69)
Incident asthma‡			
before age 4 only	0.98 (0.74 to 1.29)	1.05 (0.76 to 1.43)	0.97 (0.74 to 1.27)
after age 4 only	1.23 (0.83 to 1.84)	1.20 (0.76 to 1.90)	1.34 (0.90 to 2.00)
all ages	1.06 (0.85 to 1.33)	1.10 (0.85 to 1.43)	1.13 (0.90 to 1.41)
Wheeze‡	1.00 (0.86 to 1.17)	1.10 (0.92 to 1.31)	1.06 (0.92 to 1.22)
Asthma symptoms‡	1.08 (0.91 to 1.28)	1.13 (0.93 to 1.38)	1.08 (0.92 to 1.26)
LRTI‡§	1.08 (0.92 to 1.27)	1.13 (0.94 to 1.36)	1.10 (0.94 to 1.28)
Hay fever ever	0.79 (0.55 to 1.14)	1.07 (0.68 to 1.67)	0.83 (0.59 to 1.18)
Nasal symptoms‡	1.17 (1.00 to 1.37)	1.32 (1.09 to 1.59)	1.22 (1.06 to 1.41)
Atopic eczema‡	0.97 (0.83 to 1.14)	0.95 (0.79 to 1.14)	0.99 (0.86 to 1.14)
Wheeze phenotype			
Early transient	0.89 (0.72 to 1.11)	0.95 (0.74 to 1.23)	
Late onset	0.85 (0.55 to 1.32)	0.75 (0.47 to 1.22)	
Persistent	1.30 (0.91 to 1.87)	1.42 (0.93 to 2.17)	
At age 8 years			
Allergic sensitisation¶			
Any allergen	0.73 (0.56 to 0.96)	1.31 (0.97 to 1.77)	1.20 (0.92 to 1.57)
Inhalant allergens	0.78 (0.59 to 1.04)	1.34 (0.97 to 1.85)	1.33 (1.00 to 1.78)
Grass and/or birch pollen	0.77 (0.53 to 1.12)	1.63 (1.04 to 2.56)	1.25 (0.85 to 1.82)
Food allergens	0.82 (0.57 to 1.17)	1.06 (0.72 to 1.58)	1.06 (0.75 to 1.51)
BHR**	0.94 (0.65 to 1.36)	1.24 (0.82 to 1.89)	1.12 (0.77 to 1.62)

*Adjusted for gender, maternal education, parental history of atopy, study arm, study region, breastfeeding, presence of older siblings, environmental tobacco exposure in the home, signs of dampness in living room and child's bedroom, pets in the child's home, day-care attendance in the first year of life and relocation during first 8 years of life.

†Number of subjects included in the analyses, N=3590.

‡In the past 12 months.

§Low respiratory tract infection.

¶N=1699.

**Bronchial hyper responsiveness, N=929.

showed no conflicting results and the associations remained statistically significant. The observed associations for nasal symptoms, hay fever and allergic sensitisation in the present study were not consistent; for example, we noticed non-significant effect estimates below 1.0 for hay fever. The reason for this inconsistency is not clear. It may be partly attributable to the fact that questions on nasal symptoms and hay fever referred to different time-period, that is, the past 12 months versus ever, but we cannot test this. Overall, given these inconsistencies, we think that we cannot draw definite conclusions about the role of gas cooking in the development of hay fever, yet.

Some studies addressing gender differences in sensitivity to indoor NO₂ and its sources found that girls might be more susceptible to and/or more exposed to gas cooking/heating fumes than boys;^{28 29} others did not.^{12 30} In our study, gas cooking exposure was not significantly associated with reported respiratory illnesses in either boys or girls, except for prevalent asthma, nasal symptoms and allergic sensitisation to inhalant allergens. The risk of prevalent asthma was higher among girls than boys; in contrast, the risk of allergic sensitisation to inhalant allergens was higher among boys than girls. Belanger and Triche⁵ reviewed the most recent epidemiological literature and suggested that besides the difference of exposure time spent in kitchens, hormonal differences might play a role.

Our study has a prospective design and longitudinal data analysis of repeated observations of exposure and health endpoints.

Previous studies were often based on cross-sectional analyses.^{12 14 16 18 26 31 32} In our study, associations between gas cooking and respiratory health in particular nasal symptoms were found at some but not all time points studied, which in itself may explain why some studies, using cross-sectional analyses only, find an effect and others do not.

Another strength of our study is that the longitudinal data analysis allows us to characterise changes in exposure–response relationships over time. An important question about the association between gas cooking and respiratory health is whether the association may be modified by age of exposure. One study reported an association between exposure to domestic gas cooking during infancy indoor aeroallergen sensitisation and lung function deficits during an 8-year follow-up³³ and with childhood asthma during a 7-year follow-up (OR=1.84, 95% CI 1.06 to 3.17) after adjustment for environmental tobacco smoke.³⁴ No analysis was made of exposure during other time periods, however.

A third strength is that we took the gas cooking exposure pattern into account. Most previous gas cooking studies used a dichotomous variable (using or not using gas for cooking) to characterise either early life or current exposure. With a reasonable postulation that the use of gas for cooking in the child's home would not change if they did not relocate, children in this study were categorised into never, intermittently and always exposed groups. Excluding children with home renovation during the first 5 years did not modify our main results.

Table 3 Adjusted associations between gas cooking and respiratory outcomes by gender or allergic status

Health outcomes	Ever used gas cooking versus never used OR* (95% CI)			
	Boy (N=1866)	Girl (N=1724)	Non-allergy (N=1149)	Allergy (N=542)
Ever versus never exposed	1586 vs 280	1521 vs 203	970 vs 179	470 vs 72
During the first 8 years				
Prevalent asthma†	1.03 (0.71 to 1.50)	1.97 (1.05 to 3.72)	0.85 (0.48 to 1.51)	1.22 (0.58 to 2.57)
Incident asthma†	0.96 (0.71 to 1.29)	1.57 (0.94 to 2.65)	0.98 (0.62 to 1.54)	1.04 (0.60 to 1.79)
Wheeze†	1.08 (0.86 to 1.36)	1.13 (0.86 to 1.50)	0.88 (0.64 to 1.21)	0.94 (0.60 to 1.48)
Asthma symptomst	1.14 (0.88 to 1.47)	1.12 (0.84 to 1.49)	1.05 (0.74 to 1.50)	0.94 (0.57 to 1.55)
LRTI†‡	1.16 (0.91 to 1.49)	1.12 (0.84 to 1.49)	0.99 (0.74 to 1.33)	1.42 (0.80 to 2.53)
Hay fever ever	1.25 (0.72 to 2.19)	0.75 (0.36 to 1.56)	1.23 (0.30 to 4.97)	2.11 (0.83 to 5.37)
Nasal symptomst	1.28 (1.00 to 1.62)	1.39 (1.03 to 1.86)	1.24 (0.89 to 1.73)	1.59 (0.99 to 2.57)
Atopic eczemat	1.04 (0.82 to 1.32)	0.84 (0.64 to 1.11)	0.84 (0.60 to 1.16)	0.88 (0.56 to 1.38)
At age 8 years				
Allergic sensitisation§				
Any allergen	1.24 (0.83 to 1.84)	1.41 (0.89 to 2.24)		
Inhalant allergens	1.52 (1.00 to 2.31)	1.10 (0.67 to 1.81)		
Grass and/or birch pollen	1.80 (1.04 to 3.10)	1.31 (0.60 to 2.86)		
Food allergens	0.89 (0.53 to 1.49)	1.34 (0.73 to 2.48)		
BHR¶	1.13 (0.65 to 1.95)	1.42 (0.74 to 2.72)	1.30 (0.71 to 2.37)	1.27 (0.62 to 2.62)

*Adjusted for gender (in analysis stratified for allergy status), maternal education, parental history of atopy, study arm, study region, breast feeding, presence of older siblings, environmental tobacco exposure in the home, signs of dampness in living room and child's bedroom, pets in the child's homes, day-care attendance in the first year of life and relocation during first 8 years of life.

†In the past 12 months.

‡Lower respiratory tract infection.

§N=1699 (boy vs girl=876 vs 823).

¶N=929 (boy vs girl=462 vs 467); N=781 (non-allergy vs allergy=424 vs 357).

Possible limitations of our study have to be considered. One limitation may be that the number of children without exposure to gas cooking was low (13.5%). However, the imbalance between exposed and unexposed children is common to many studies in this field.^{6 11 12 14} Another possible limitation is that health and exposure outcomes were reported by the parents. However, we also collected objective data on allergic sensitisation and BHR, which could not be influenced by potential parental suspicion of an association between gas cooking and health. Information on gas cooking exposure was not available for ages 6–8 years in our study. Misclassification of gas cooking exposure may have occurred if moving was associated with changes in cooking appliance. However, the number of movers during ages 6–8 was small and results remained unchanged after exclusion of participants who moved between 6 and 8 years.

In conclusion, our findings provide little evidence for an adverse effect of exposure to gas cooking on the development of asthma and allergies until the age of 8 years.

What this paper adds

- Gas cooking is an important source of indoor nitrogen dioxide and ultrafine particles that may affect the development of respiratory illnesses in children.
- Evidence for a relationship between gas cooking and childhood respiratory health is inconsistent and few longitudinal studies have been reported.
- Based on a prospective birth cohort study and longitudinal analysis, this paper provides little evidence for an adverse effect of exposure to gas cooking on the development of asthma and allergies.

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Contributors BB, JCJ and HAS were responsible for the conception and design of the study. MK and MO contributed to the data collection and data management. WL and UG contributed to the data analysis. All authors contributed to the interpretation of data. WL wrote the manuscript; all other authors critically reviewed the manuscript and approved the final version of the manuscript for submission.

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Competing interests Dr Postma reports receiving grant support from AstraZeneca, Chiesi and GSK.

Ethics approval The study was approved by the Medical Ethical Committees of the participating institutions.

Provenance and peer review Not commissioned; externally peer reviewed.

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Gas cooking, respiratory and allergic outcomes in the PIAMA birth cohort study

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Supplemental Material

Gas Cooking, Respiratory and Allergic Outcomes in the PIAMA Birth Cohort Study

Weiwei Lin, Ulrike Gehring, Marieke Oldenwening, Johan C. de Jongste, Marjan Kerkhof,
Dirkje Postma, Henriette A. Smit, Alet H. Wijga, Bert Brunekreef

METHODS

Definition of health outcomes

At age 8, immunoglobulin E (IgE) was collected in children who gave consent, and bronchial hyperresponsiveness (BHR) were measured in all children of allergic mothers and a random selection of children of non-allergic mothers, according to the protocol of the European Community Respiratory Health Survey.¹ Specific IgE levels for house dust mite (*Dermatophagoides pteronyssinus*), cat, dog, birch and grass (*Dactylis glomerata*) pollen, *Alternaria alternata*, egg and milk were measured in blood samples by a radioallergosorbent test-like method used at the Sanquin Laboratories (Amsterdam, The Netherlands). Sensitization was defined as a positive reaction (IgE level >0.35 IU/ml) to one of the allergens tested (house dust mite *Dermatophagoides pteronyssinus*, cat, dog, cocksfoot and birch pollen, *Alternaria Alternata*, egg and milk); sensitization against inhalant and food allergens was defined as a positive reaction to one of the inhalant or food allergens tested, respectively. For BHR measurement, KoKo or Rosenthal-French dosimeter and DeVilbiss 646 nebulizers were used to nebulizer methacholine bromide with an air pressure of 30 psi (2 bars) up to a cumulative dose of 2.46 mg. A short protocol with four-fold increases or a long protocol with two-fold increases in methacholine concentration was used, choice based on absence or presence of a history of respiratory symptoms (wheeze during the past 12 months; shortness of breath during the past 12 months; symptoms of cough for a period of at least 3 months during one year; exercise induced shortness of breath; doctor-diagnosed asthma). BHR was defined as a decrease in FEV₁ of 20% or more at a cumulative dose of methacholine bromide not exceeding 0.61 mg.

Statistical methods

Sensitivity analyses

Exposure ever was defined by information on gas cooking until age 5. Moving to another house after age 5 years might have resulted in exposure misclassification. Therefore, a

sensitivity analysis was performed by excluding children who moved between ages 6-8 years.

In addition to these analyses, risk of current gas cooking exposure and early gas cooking exposure at age 1 were included to account for the effects of time-varying and early exposure on health outcomes repeatedly observed during the 8 years of follow-up with GEE models.

To test for modification of the ever gas cooking effect by gender, analyses with gender-gas cooking interaction terms were performed.

Confounders

Potential confounders such as gender, maternal education, parental history of allergies, study arm (intervention study with active mattress covers, intervention study with placebo mattress covers, natural history), study region, breastfeeding at age 3 months, presence of older siblings, environmental tobacco smoke (ETS) exposure at home, home dampness, pets in the child's home, and daycare attendance during the first year of life were selected and investigated. In addition, moving house during the first 8 years of life was also included as a potential confounder because moving to another house may be associated with changes in exposures other than gas cooking. Maternal education was categorized into three groups: low, intermediate and high. Home dampness was defined as any moisture stains or mold on the ceiling or walls seen in a living room and/or child's bedroom in the past 12 months. ETS exposure was defined as any smoking at the child's home more than once a week. Home dampness, ETS and pets at home were time-varying variables, which were assessed by yearly questionnaires completed by the parents.

Figures

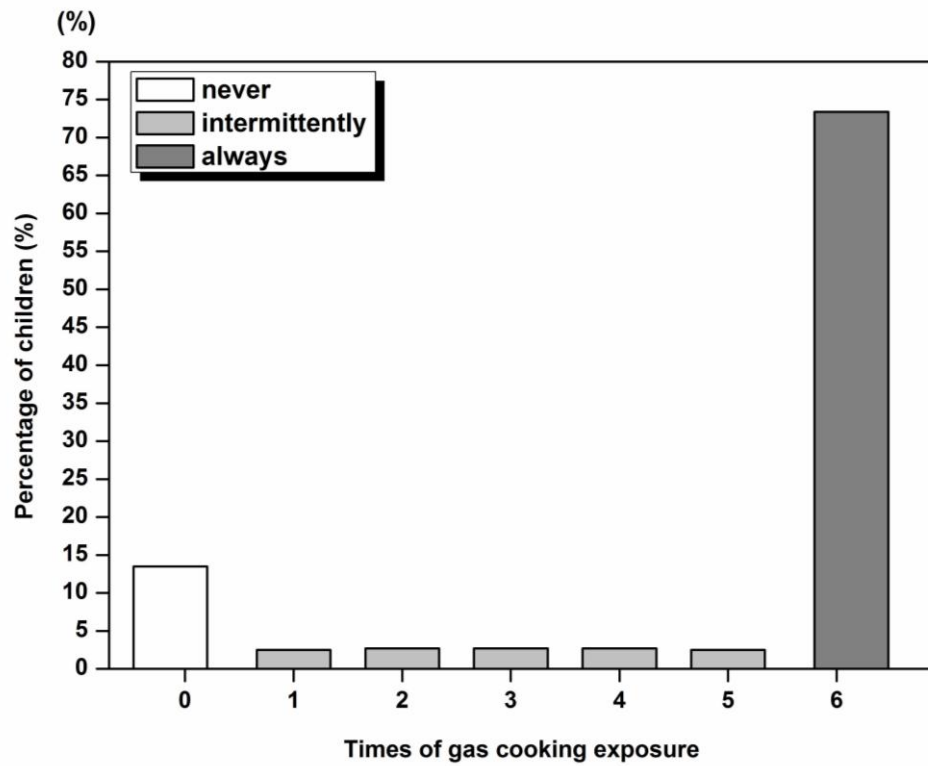


Figure E1. Frequency distribution of the number of time points (questionnaires) with gas cooking exposure from 3 months to 5 years of age in Children (N=3059).

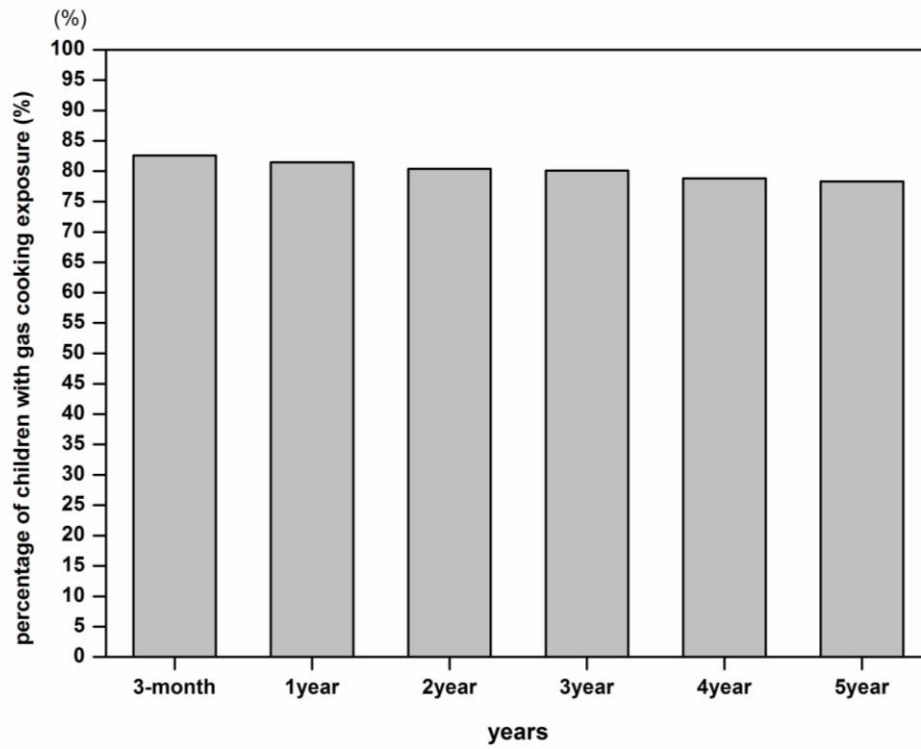


Figure E2. Percentage of children (N=3590) with gas cooking exposure from age 3 months to 5 years.

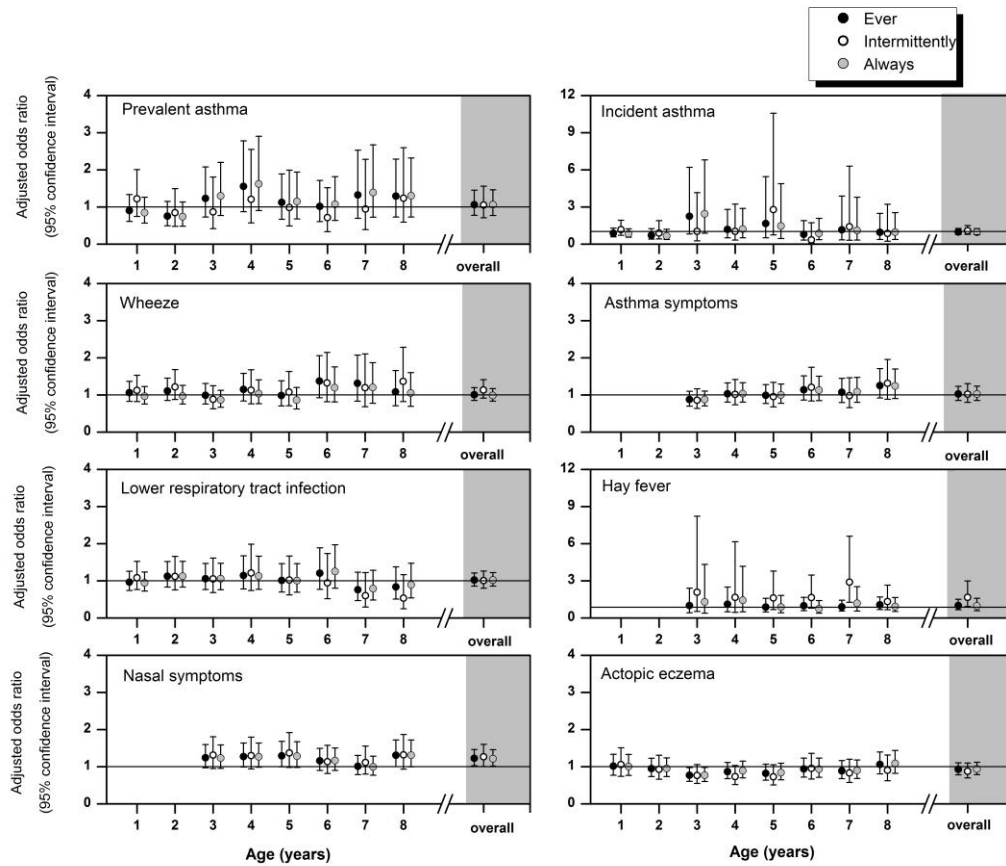


Figure E3. Crude age-specific and overall association between ever, intermittent and always exposure to gas cooking and health outcomes during the first 8 years of child's life. Results are presented as adjusted odds ratios (OR) with 95% confidence intervals.

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