ORIGINAL ARTICLE

Exposure to indoor combustion and adult asthma outcomes: environmental tobacco smoke, gas stoves, and woodsmoke

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Background: Because they have chronic airway inflammation, adults with asthma may be particularly susceptible to indoor air pollution. Despite widespread exposure to environmental tobacco smoke (ETS), gas stoves, and woodsmoke, the impact of these exposures on adult asthma has not been well characterised.
Methods: Data were used from a prospective cohort study of 349 adults with asthma who underwent structured telephone interviews at baseline and 18 month follow up. The prospective impact of ETS, gas stove, and woodsmoke exposure on health outcomes was examined.
Results: ETS exposure at baseline interview was associated with impaired health status at longitudinal follow up. Compared with respondents with no baseline self-reported exposure to ETS, higher level exposure ($\geqslant$7 hours/week) was associated with worse severity of asthma scores at follow up, controlling for baseline asthma severity, age, sex, race, income, and educational attainment (mean score increment 1.5 points; 95% CI 0.4 to 2.6). Higher level baseline exposure to ETS was also related to poorer physical health status (mean decrement –4.9 points; 95% CI –8.4 to –1.3) and asthma specific quality of life (mean increase 4.4 points; 95% CI –0.2 to 9.0) at longitudinal follow up. Higher level baseline ETS exposure was associated with a greater risk of emergency department visits (OR 3.4; 95% CI 1.1 to 10.3) and hospital admissions for asthma at prospective follow up (OR 12.2; 95% CI 1.5 to 102). There was no clear relationship between gas stove use or woodstove exposure and asthma health outcomes.
Conclusion: Although gas stove and woodstove exposure do not appear negatively to affect adults with asthma, ETS is associated with a clear impairment in health status.

Because adults spend the majority of their time indoors, the quality of household air may have important health effects.[1 2] Adults with asthma who have chronic airway inflammation may be particularly susceptible to the effects of indoor air pollutants.[1 3] Despite these potential health risks, few studies have examined the effects of indoor air pollution on adults with asthma.

In the home, combustion is a major source of indoor air pollution. In particular, gas stove use, wood burning in fireplaces or stoves, and environmental tobacco smoke (ETS) are the principal indoor combustion sources.[1] Of these exposures, ETS has received the most attention. Among children, extensive evidence indicates that ETS exposure can exacerbate asthma.[2] In contrast, data on the effects of ETS exposure on adults with asthma are surprisingly limited.[3–7] The effects of other common indoor combustion sources on adult asthma—such as gas stoves, wood stoves, and fireplaces—have received even less attention.[3 8–10] In a prospective cohort study of adults with asthma, we evaluated the impact of exposure to ETS, gas stoves, and woodsmoke on health outcomes.

METHODS

Overview and subject recruitment

The data used in this study were collected during a prospective longitudinal cohort study of adults with asthma. We examined the influence of exposure to indoor combustion—including ETS, gas stoves, and woodsmoke—on health status at longitudinal follow up. The study was approved by the University of California, San Francisco committee on human research.

Details of recruitment and initial follow up have been previously reported.[11–13] Beginning in 1995, we initially recruited adults with asthma from a random sample of board certified pulmonary specialists, allergy/immunology specialists, and family practitioners in Northern California. Baseline data from interviews conducted between July 1998 and December 1999 were used, with a follow up interview approximately 18 months later. Of the 401 baseline respondents, 349 (87%) completed follow up interviews.

Compared with the 349 subjects who completed both baseline and 18 month follow up interviews, the 52 subjects who did not complete follow up were similar in age (43.3 *v* 44.2 years), sex (67% *v* 72% female), race-ethnicity (67% *v* 73% white, non-Hispanic), and smoking history (39% *v* 36% ever smoked cigarettes) (p>0.4 in all cases).

Exposure to indoor combustion

Each subject underwent structured computer assisted telephone interviews that assessed sociodemographic characteristics, environmental exposures, asthma history, and health status. In both baseline and follow up interviews we ascertained gas stove use with the following question: "Is there a gas cooking stove, range, or oven in your household?" Those subjects with a gas stove in their household were then asked: "On average, how many meals per week do you yourself prepare using this gas cooking stove, range, or oven?" Based on the distribution of responses, lower level exposure was defined as personal gas stove use of 1–6 times per week and higher level exposure as gas stove use of $\geqslant$7 times per week. These definitions corresponded to our a priori assumption that daily gas stove use corresponds approximately to $\geqslant$7 times per week.

We also assessed woodsmoke exposure, asking: "In the past 12 months, have you used a wood stove or fireplace to heat your living space?" Subjects who responded in the affirmative were then asked: "During an average winter month, how many times per week did you typically use such heating?" Based on the distribution of winter weekly use, lower level woodsmoke exposure was defined as wood stove or fireplace use 1–4 times per week and higher level exposure as ⩾5 times per week.

We have previously developed and validated a survey instrument that assesses recent ETS exposure.[7] The instrument, which was tailored for adults with asthma living in Northern California, assesses exposure during the past 7 days in six microenvironments: the respondent's home, another person's home, travelling in a car or another vehicle, workplace, bars and nightclubs, and other locations. In each area, the instrument ascertains the total duration (in hours) of exposure during the past 7 days. In each location, exposure related sensory irritation symptoms (eye and nose irritation) are also assessed. Based on the distribution of responses, we defined lower level (1–2 hours/week) and higher level (⩾3 hours/week) exposure categories.

Table 1 Baseline characteristics of 349 adults with asthma

Mean (SD) age (years)	44.2 (7.7)
Sex (% female)	250 (72%)
White, non-Hispanic race-ethnicity	254 (73%)
Education	
High school or less	56 (16%)
Some college	131 (38%)
College or graduate degree	162 (46%)
Household income	
Low income (<$20000)	26 (7%)
Intermediate income ($20001–74999)	212 (61%)
High income (>$75000)	111 (32%)
Married (or cohabitating)	251 (72%)
Atopic history	274 (79%)
Smoking	
Ever	127 (36%)
Current	23 (7%)
Mean (SD) severity of asthma score	9.5 (5.6)
Mean (SD) SF-12 physical component summary score	45.7 (11.4)
Mean (SD) asthma specific QOL score	16.4 (14.5)

Asthma health outcomes

The impact of indoor combustion exposure was examined on two sets of health outcome measures: disease severity/health status and health care utilisation for asthma. Asthma severity was measured using a previously developed and validated 13 item disease specific severity of asthma score based on frequency of current asthma symptoms (daytime or nocturnal), use of systemic corticosteroids, use of other asthma medications (besides systemic corticosteroids), and history of hospitalisations and intubations.[11 12] Possible total scores range from 0 to 28, with higher scores reflecting more severe asthma.

Generic physical health status was measured using the SF-12 questionnaire.[14] The physical component summary score, which was defined from the original eight SF-36 subscales by factor analysis, measures an underlying physical dimension of health.[14] Previous work has confirmed the validity of the SF-12 instrument in adult asthma.[15] Higher scores reflect more favourable health states.

Asthma specific quality of life was assessed using the Marks Asthma Quality of Life Questionnaire (AQLQ), a 20 item questionnaire that measures the physical, emotional, and social impact of asthma.[16] Individual items are scored from 0 ("not at all") to 4 ("very severely"), and a total score ranging from 0 to 80 can be calculated. The total score can be converted to a 0 to 10 scale (by multiplying the score by 2.5 and then dividing by 10). Higher scores represent poorer asthma specific quality of life. To adapt the AQLQ for telephone administration, the number of response options for each question was reduced from five to four, consistent with the response format used in the instrument's development.[16] The total score ranges from 0 to 60 points. Using this modified approach, we have previously demonstrated the validity of the AQLQ[16 17] and its responsiveness to change in asthma status.[17]

During each interview the use of health care for asthma during the previous 12 months was assessed. Subjects were asked whether they had emergency department visits or hospital admissions for asthma. Although subjects could indicate more than one event in each category, we analysed binary outcome variables (one or more emergency department visit or hospital admission).

Statistical analysis

Interview data were analysed using SAS 8.2 (SAS Institute, Cary, NC). Linear regression or logistic regression analysis was used to examine the prospective impact of gas stove use on asthma severity, health status, and health care utilisation at 18 month follow up, controlling for baseline asthma severity. Lower level and higher level gas stove users were compared with non-users (referent group). We then examined the impact of change in weekly gas stove use during the 18 month follow up period, controlling for baseline asthma severity: increasing use, decreasing use, or continued similar use. These change categories were defined by comparing lower and higher level use categories at both baseline and follow up interviews. For both sets of analyses we performed further multivariate regression to control for sociodemographic factors that could confound the relation between gas stove use and health status. The same analytical approach was used to evaluate the health impacts of exposure to woodsmoke.

We used a similar analysis strategy to examine the influence of baseline ETS exposure on prospective health outcomes. These analyses were restricted to non-smokers (n=326). Lower and higher levels of ETS exposure were compared with a referent group without exposure. As an alternative measure of higher level ETS exposure,[7] ETS related sensory irritation symptoms—defined as self-reported eye or nose irritation following ETS exposure—were measured. We did not evaluate change in ETS exposure between the two interviews because exposure was assessed for the 7 day period before the telephone interview rather than exposure for an average period (as for gas stove or woodsmoke). The potential for asthma status influencing ETS exposure would therefore complicate such an analysis.

For all three exposures (gas stoves, woodsmoke, ETS) and both sets of study outcomes (health status and healthcare utilisation) we examined potentially confounding variables including age, sex, race, income, educational attainment, marital status, smoking (past and present), and atopic status. To construct the most parsimonious multivariate analyses we only included covariates that were statistically associated with at least one outcome variable using a liberal p value cut off of ⩽0.20 or that changed a regression coefficient for exposure by >10%. In addition to baseline asthma severity, the covariates included in the final multivariate analyses were age, sex, educational attainment, and income.

We reasoned that the impact of ETS exposure on asthma could be modified by exposure to gas stoves or woodsmoke. For example, ETS exposure could have a greater negative effect on individuals who also have exposure to gas stoves or woodsmoke. To examine this possibility we evaluated statistical interactions between any baseline ETS exposure and any baseline gas stove or woodsmoke exposure.

The statistical power for exposed *v* unexposed groups for ETS exposure, gas stove use, and woodsmoke exposure was

Table 2 Longitudinal analysis of ETS exposure and health status at 18 month follow up (n=326 non-smokers)

ETS exposure measure	n (%)	Asthma severity: B coefficient* (95% CI)	Asthma severity: Multivariate B coefficient† (95% CI)	Physical health status: B coefficient* (95% CI)	Physical health status: Multivariate B coefficient† (95% CI)	Asthma-specific QOL: B coefficient* (95% CI)	Asthma-specific QOL: Multivariate B coefficient† (95% CI)
Baseline exposure: any *v* none							
None	243 (75%)	–	–	–	–	–	
Any exposure, past 7 days	83 (25%)	**0.8 (0.02 to 1.6)**	0.6 (-0.1 to 1.4)	–2.2 (–4.7 to 0.2)	–2.0 (–4.4 to 0.5)	**3.3 (0.2 to 6.5)**	2.8 (–0.4 to 6.0)
Baseline exposure, past 7 days							
None	243 (75%)	–	–	–	–	–	–
Lower exposure (1–2 h/week)	49 (15%)	0.07 (–0.9 to 1.0)	0.07 (–3.0 to 2.9)	0.3 (–2.7 to 3.2)	–0.07 (–3.0 to 2.9)	1.5 (–2.3 to 5.3)	1.7 (–2.1 to 5.5)
Higher exposure (⩾3 h/week)	34 (10%)	**1.8 (0.7 to 2.9)**	**1.5 (0.4 to 2.6)**	**–5.8 (–9.3 to -2.3)**	**–4.9 (–8.4 to –1.3)**	**6.0 (1.5 to 10.5)**	4.4 (–0.2 to 9.0)
Baseline ETS related sensory irritation‡							
None	278 (85%)	–	–	–	–	–	–
Any eye or nose irritation	48 (15%)	0.7 (–0.3 to 1.6)	0.4 (–0.5 to 1.4)	**–4.9 (–7.9 to –1.9)**	**–4.0 (–7.0 to –1.0)**	**6.3 (2.5 to 10.2)**	**5.0 (1.2 to 8.9)**

*Linear regression analysis to evaluate impact of baseline exposure on outcome at 18 months, controlling for baseline severity of asthma score.
†Controlling for baseline severity of asthma score and other covariates: age, sex, income, educational attainment.
‡Reported eye or nose irritation after ETS exposure, past 7 days.

estimated using a two tailed alpha of 0.05. For continuous outcome variables the study had a 90% power to detect an effect size of 0.35 for gas stove use, 0.38 for woodsmoke exposure, and 0.41 for ETS exposure. The corresponding score ranges were: 2.0–2.4 points (severity of asthma score), 5.1–6.0 points (ALQL score), and 3.8–4.5 points (physical health status score). To illustrate statistical power for dichotomous outcomes, we estimated the power to detect an increased risk of emergency department visits. The study had an 80% power to detect a relative risk ranging from 2.1 (for gas stoves) to 2.36 (for ETS exposure).

RESULTS

Demographic and personal characteristics of the study subjects are shown in table 1. Most were female, white, and non-smokers.

At baseline interview a substantial minority of adults with asthma reported some ETS exposure during the past 7 days (25%; 95% CI 21 to 31). Of these subjects, 15% and 10% reported lower and higher level exposure, respectively.

ETS exposure at baseline interview was associated with impaired health status at longitudinal follow up (table 2). Compared with respondents with no baseline self-reported ETS exposure, higher level baseline ETS exposure was associated with worse severity of asthma scores at follow up, controlling for baseline asthma severity, age, sex, income, and educational attainment (mean score increment 1.5 points; 95% CI 0.4 to 2.6). Higher level baseline ETS exposure was also related to poorer physical health status at follow up (mean score decrement –4.9 points; 95% CI –8.4 to –1.3), controlling for the same covariates. After controlling for asthma severity only, higher baseline ETS exposure was associated with impaired asthma specific quality of life 18 months later (mean score increment 6.0 points; 95% CI 1.5 to 10.5). When the additional covariates were added to the analysis, ETS was still associated with a decrement in quality of life, but the 95% CI no longer excluded no relationship (4.4 points; 95% CI –0.2 to 9.0).

When baseline ETS exposure was defined as any versus none, the same pattern of results was observed although the confidence intervals included 1.0 in some cases (table 2). Baseline ETS related sensory irritation symptoms such as eye or nose irritation were associated with worse physical health status (–4.0 points; 95% CI –7.0 to –1.0) and asthma specific quality of life at longitudinal follow up (5.0 points; 95% CI 1.2 to 8.9).

ETS exposure was also linked with greater healthcare utilisation for asthma during prospective follow up (table 3). Higher level baseline ETS exposure was associated with a greater risk of emergency department visits (OR 3.4; 95% CI 1.1 to 10.3) and hospital admissions for asthma during the 18 month follow up period (OR 12.2; 95% CI 1.5 to 102) after controlling for baseline asthma severity and other covariates. Furthermore, adult asthmatics who reported recent ETS related sensory irritation symptoms at baseline interview had

Table 3 Longitudinal analysis of ETS exposure and health care utilization at 18 month follow up

ETS exposure measurement	Emergency department visits: OR (95% CI)*	Emergency department visits: Multivariate† OR (95% CI)	Hospital admissions: OR (95% CI)*	Hospital admissions: Multivariate† OR (95% CI)
Baseline exposure: any *v* none				
None	–	–	–	–
Any exposure, past 7 days	**3.1 (1.4 to 6.8)**	**2.8 (1.2 to 6.4)**	**4.2 (1.03 to 16.8)**	**6.6 (1.3 to 33)**
Baseline exposure, past 7 days				
None	–	–	–	–
Lower exposure (1–2 h/week)	**2.6 (1.02 to 6.8)**	2.5 (0.93 to 6.6)	3.6 (0.7 to 19)	4.6 (0.7 to 40)
Higher exposure (⩾3 h/week)	**3.9 (1.4 to 11.3)**	**3.4 (1.1 to 10.3)**	5.2 (0.8 to 34)	**12.2 (1.5 to 102)**
Baseline ETS related sensory irritation‡				
None	–	–	–	–
Any eye or nose irritation	**3.0 (1.3 to 7.3)**	**2.7 (1.1 to 6.6)**	2.1 (0.4 to 10.3)	2.4 (0.4 to 13.1)

*Logistic regression analysis to evaluate impact of baseline exposure on outcome at 18 months, controlling for baseline severity of asthma.
†Logistic regression analysis controlling for baseline severity of asthma score and additional covariates: age, sex, income, educational attainment.
‡Reported eye or nose irritation after ETS exposure, past 7 days

Table 4 Longitudinal analysis of gas stove and wood fireplace use and health status at 18 month follow up

Exposure	n (%)	Asthma severity: Multivariate B coefficient (95% CI)†	Physical health status: Multivariate B coefficient (95% CI)†	Asthma specific QOL: Multivariate B coefficient (95% CI)†
Personal gas stove use:				
Baseline use				
None	195 (56%)	–	–	–
Lower use (1–6 times/week)	100 (29%)	0.4 (–0.3 to 1.2)	0.7 (–1.6 to 3.1)	–0.6 (–3.6 to 2.5)
Higher use (≥7 times/week)	54 (15%)	0.1 (–0.9 to 1.0)	–0.4 (–3.4 to 2.5)	–1.8 (–5.6 to 2.0)
Change in use over time				
No use, either interview	160 (46%)	–	–	–
Continued use	100 (29%)	0.6 (–0.1 to 1.4)	–1.3 (–3.7 to 1.1)	1.5 (–1.6 to 4.7)
Increased use	48 (14%)	–0.4 (0.6 to –1.4)	–0.2 (–3.3 to 3.0)	0.8 (–3.2 to 4.8)
Decreased use	41 (12%)	–0.6 (–1.7 to 0.4)	2.3 (–1.1 to 5.6)	–3.7 (–8.0 to 0.6)
Wood fireplace or stove use:				
Baseline use‡				
None	242 (69%)	–	–	
Lower use (1–4 times/week)	50 (14%)	–0.2 (–1.0 to 0.9)	–0.1 (–3.1 to 2.9)	–0.5 (–4.4 to 3.4)
Higher use (≥5 times/week)	57 (16%)	–0.3 (–1.2 to 0.7)	–0.7 (–3.7 to 2.2)	**4.1 (0.4 to 7.9)**
Change in use over time				
No use, either interview	209 (60%)	–	–	–
Continued use	55 (16%)	–0.3 (–1.3 to 0.6)	0.4 (–2.6 to 3.4)	0.5 (–3.4 to 4.3)
Increased use	42 (12%)	–0.1 (–1.1 to 0.9)	1.4 (–1.9 to 4.6)	–0.6 (–4.8 to 3.5)
Decreased use	43 (12%)	–0.3 (–1.3 to 0.7)	–0.4 (–3.7 to 2.8)	3.3 (–0.9 to 7.5)

Higher severity of asthma scores = more severe asthma; higher SF–12 physical component summary scores = better health status; higher asthma specific QOL scores = poorer QOL.
†Multivariate linear regression analysis to evaluate impact of baseline exposure on outcome at 18 months, controlling for baseline severity of asthma score and other covariates: age, sex, educational attainment, income.
‡During an average winter wkeek.

a greater risk of emergency department visits at longitudinal follow up (OR 2.7; 95% CI 1.1 to 6.6).

There was no statistical association between baseline gas stove use and asthma severity, physical health status, or asthma specific quality of life at 18 month follow up, controlling for baseline asthma severity (data not shown). Decreased gas stove use during the 18 month study period was related to improvement in asthma specific quality of life score (mean reduction –4.7 points; 95% CI –9.1 to –0.3). After controlling for additional covariates in multivariate analysis, there was no statistical association between gas stove use and asthma severity, physical health status, or asthma specific quality of life (table 4). There was also no relation between gas stove use and emergency department visits or hospital admissions for asthma during prospective follow up (table 5).

At baseline, higher level use of wood fireplaces or stoves was associated with worse asthma specific quality of life at longitudinal follow up (table 4). There was no statistical association between woodsmoke exposure and other health outcomes at 18 months (tables 4 and 5).

To examine the impact of sex on the observed results we repeated all the analyses (three exposures, six health

Table 5 Longitudinal analysis of gas stove and wood fireplace use and health care utilisation at 18 month follow up

Exposure	Emergency department visits: OR (95% CI)*	Emergency department visits: Multivariate† OR (95% CI)	Hospital admissions: OR (95% CI)*	Hospital admissions: Multivariate† OR (95% CI)
Personal gas stove use:				
Baseline use				
None	–	–	–	–
Lower use (1–6 times/week)	1.2 (0.5 to 2.7)	1.2 (0.5 to 2.7)	1.6 (0.5 to 5.5)	1.5 (0.4 to 5.0)
Higher use (≥7 times/week)	1.1 (0.4 to 2.9)	1.1 (0.4 to 3.1)	0.4 (0.1 to 3.7)	0.4 (0.05 to 3.8)
Change in use over time				
No use, either interview	–	–	–	–
Continued use	1.0 (0.4 to 2.4)	1.0 (0.4 to 2.4)	0.9 (0.3 to 3.3)	0.9 (0.2 to 3.4)
Increased use	1.9 (0.7 to 5.2)	1.8 (0.6 to 5.1)	0.9 (0.2 to 5.5)	1.1 (0.2 to 6.9)
Decreased use	1.7 (0.5 to 5.1)	1.8 (0.6 to 5.7)	0.9 (0.1 to 8.6)	1.1 (0.1 to 9.9)
Wood fireplace or stove use:				
Baseline use‡				
None	–	–	–	–
Lower use (1–4 times/week)	1.0 (0.3 to 2.8)	1.0 (0.3 to 3.0)	1.9 (0.4 to 8.9)	2.5 (0.5 to 11)
Higher use (≥5 times/week)	0.7 (0.2 to 2.1)	0.7 (0.2 to 2.5)	0.3 (0 to 3.0)	0.4 (0 to 4.8)
Change in use over time				
No use, either interview	–	–	–	–
Continued use	0.8 (0.2 to 2.4)	0.9 (0.3 to 3.0)	0.6 (0.1 to 5.5)	1.1 (0.1 to 11.1)
Increased use	0.6 (0.2 to 2.3)	0.7 (0.2 to 2.5)	0.5 (0 to 4.5)	0.8 (0.1 to 7.8)
Decreased use	0.8 (0.2 to 2.5)	0.8 (0.2 to 2.6)	0.7 (0.1 to 4.4)	0.9 (0.1 to 5.9)

*Logistic regression analysis to evaluate impact of baseline exposure on outcome at 18 months, controlling for baseline severity of asthma.
†Logistic regression analysis controlling for baseline severity of asthma score and additional covariates:age, sex, income, educational attainment.
‡During an average winter week.

outcomes) in women only (n=250). Although there was no statistical evidence of a sex-exposure interaction (p=0.46), decreased gas stove use during longitudinal follow up was associated with improved physical health status in women (adjusted mean score increment 4.8; 95% CI 0.7 to 8.9). There was no comparable statistical association for men (mean score increment –3.1; 95% CI –9.0 to 2.8). Compared with the primary analyses, no other appreciable differences were seen for any other exposure-health outcome relationship.

To evaluate whether the impact of ETS exposure was modified by gas stove or woodsmoke exposure, we examined interaction terms between any baseline ETS exposure and any gas stove or woodsmoke exposure. For all health outcomes at the 18 month follow up there was no evidence of a statistical interaction (p>0.2). This suggests that these exposures do not modulate the impact of ETS on health status.

DISCUSSION

As adults spend more time indoors, the potential for indoor environmental exposures to affect subjects with asthma negatively has become more important. In a prospective cohort study we found that ETS exposure appears to increase asthma severity, worsen health status, and results in more health care utilisation for asthma. Conversely, there was no clear evidence that gas stove use or domestic woodsmoke exposure had adverse effects on adults with asthma.

ETS exposure has been strongly linked with exacerbation of pre-existing asthma in children.[2] Although adults with asthma commonly report ETS exposure as a trigger for an exacerbation of asthma,[18] the effect of exposure on adult asthma status has undergone less research.[19 20] A cross sectional study from India found that adult asthmatics reporting ETS exposure had greater medication use and worse pulmonary function.[5] In a population based study from Sweden Blanc and colleagues[4] found that regular workplace ETS exposure was cross sectionally associated with a greater risk of work associated symptomatic asthma. In a US prospective panel study of 164 adult non-smokers with asthma, ETS exposure was related to a greater risk of asthma symptoms and activity restriction.[3] There was no apparent association between ETS exposure and emergency department visits or hospital admissions for asthma. A cohort study of 619 adult HMO members with asthma found that ETS exposure was associated with a greater incidence of hospital based episodes of asthma care.[6] In addition, controlled human exposure studies indicate that ETS can cause an acute decrease in pulmonary function in adults with asthma.[2] The present study provides important additional prospective evidence linking ETS exposure with worse asthma health outcomes.

Sensory irritation symptoms after ETS exposure, such as eye or nose irritation, were longitudinally associated with impaired asthma health outcomes. Sensory irritation symptoms could reflect higher ETS exposure levels, individual sensitivity to ETS exposure, or both. Although sensory irritation symptoms became more common as the ETS exposure level increased, the proportion of subjects with sensory irritation symptoms in each ETS exposure category (none, lower, and higher) were similar (data not shown). These results indicate that sensory irritation symptoms probably reflect both the intensity of ETS exposure and individual sensitivity to it.

Domestic gas stove use releases NO_2, a potential respiratory irritant, into the indoor environment.[1] Most epidemiological studies examining the impact of gas stove use have focused on healthy members of the general population. In both children[1 21–24] and adults[1 8 10 25–29] the impact of exposure to gas stoves on respiratory symptoms and pulmonary function has been inconclusive. In the few prospective studies of healthy adults, gas stove use was associated with an increased risk of respiratory symptoms in one study,[26] whereas other investigators found no association with either respiratory symptoms[30] or pulmonary function.[31 32]

Few studies have examined the health effects of gas stove exposure in adults with asthma. Cross sectional epidemiological studies have shown an increased risk of prevalent cases of childhood asthma in homes with gas stoves compared with homes with electric stoves,[33–36] although this has not been observed in adults.[25] In adults with established asthma a prospective panel study found an association between gas stove use and increased risk of respiratory symptoms, restricted activity, and emergency department visits.[3] Another time-series analysis found a negative impact of gas stove use on daily peak expiratory flow and respiratory symptoms.[9] In contrast, a longitudinal UK cohort study found no effect of gas stove exposure on persistence of adult asthma or on respiratory symptoms among asthmatics.[37] Overall, the evidence has not been sufficient to implicate gas stove use as an exacerbating factor in pre-existing adult asthma.

The current findings do not support a deleterious effect of gas stove use on adults with asthma. Because the previous literature on gas stove use and respiratory health has been characterised by a remarkable lack of consistency, how should these results be interpreted? A key issue may be the timing and intensity of exposure. In a prospective study of 16 non-smoking asthmatic women, investigators found that acute peak NO_2 exposure during gas cooking was associated with diminished peak expiratory flow, whereas mean NO_2 exposure over a 2 week period had no impact on peak flow.[38] The deleterious consequences of acute peak NO_2 exposure on adults with asthma are supported by epidemiological studies that assessed gas stove use on a daily basis[3 9] and controlled human exposure studies of acute NO_2 exposure.[39–42] Mean daily exposure to gas stoves, as assessed by our study, appears to have no clinically meaningful impact on adults with asthma.

Woodsmoke, which is produced from domestic fireplaces or wood stoves, contains potent respiratory irritants such as formaldehyde, acrolein, nitrogen oxides, sulfur dioxide, and particulates.[43] In previous studies exposure to extremely high levels of woodsmoke has been linked with respiratory problems. After a work shift, forest firefighters experienced an acute decrease in pulmonary function.[44] Similarly, Florida wildfires were associated with increased visits to the emergency department for asthma and acute bronchitis.[45] In developing countries where prolonged wood stove use in poorly ventilated homes occurs, often in conjunction with other biomass fuels, exposure to woodsmoke has been associated with chronic respiratory symptoms.[1]

The respiratory health effects of residential woodsmoke exposure, which occurs at lower levels, have not been clearly characterised. In a small study from Michigan, children living in homes heated by wood burning stoves had a greater prevalence of cough and wheeze than those without exposure to domestic woodsmoke.[46] Similarly, children with asthma residing in a region of Seattle with high woodsmoke exposure had lower forced expiratory volume in 1 second (FEV_1) than those living in less polluted areas.[47] Other studies, however, have found no effect of the use of domestic woodsmoke stoves on respiratory symptoms in children.[34 48]

Previous evidence evaluating the effects of woodsmoke exposure on adult asthma is limited. A prospective cohort study of adults with asthma found that the use of wood stoves or fireplaces was related to more respiratory symptoms.[3] In contrast, we found no evidence of a negative influence of woodsmoke exposure on adult asthma.

Our study has several limitations. Because fireplace use is discretionary,[3] more severe asthma might result in decreased use and this could obscure a deleterious effect of woodsmoke exposure on asthma. Gas stove use could be subject to similar selection effects. In addition, exposures to gas stoves, woodsmoke, and ETS were assessed by self-reporting rather than by direct environmental sampling. As a result, we cannot exclude some misclassification of exposure status. For example, adults with poor asthma status may be more likely to perceive and report ETS exposure. Using a direct measure of personal ETS exposure, we have previously validated the ETS exposure survey instrument in this cohort of adults with asthma.[7]

Indoor combustion during gas stove cooking, fireplace use, and tobacco smoking emits respiratory irritants into the household environment. Because these practices are widespread, even a small adverse effect on respiratory health would have a significant impact on public health. Although gas stove use and woodsmoke exposure are not clearly deleterious in adults with asthma, ETS exposure appears to have a meaningful negative influence on adult asthma. Based on these results, healthcare providers should routinely assess exposure of patients to ETS and encourage its avoidance. Moreover, these results provide further support for legislation to prohibit public tobacco smoking.

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