Published in final edited form as:

Occup Environ Med. 2013 February ; 70(2): 120–125. doi:10.1136/oemed-2011-100569.

Household Solid Fuel Use and Pulmonary Function in an Urban Population in Shanghai, China

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Abstract

Objectives—We examined the association between household solid fuel exposure and lung function in a densely populated district in urban Shanghai, China.

Methods—Spirometry was performed in 12,506 subjects, aged 18 and over, residing the Putuo District in Shanghai, China, in a cross-sectional survey. Exposure to solid fuel use at home was assessed by administered questionnaire, estimating duration and total amount of solid fuel use at home during the lifetime.

Results—After adjusting for confounders, the subjects with exposure to household solid fuel had a 1.3% [95% confidence interval (CI) 0.57 to 2.02] decrease in forced expiratory volume in 1 sec (FEV₁) percent predicted and 3.5% (95% CI 2.74 to 4.18) decrease in forced vital capacity (FVC) percent predicted, respectively. Trends towards decreased pulmonary function measures were seen for longer duration and greater amount of household fuel use at home, in the highest compared with lowest tertile (*P* values for trend < 0.001). We observed decrease in FEV₁ and FVC percent predicted across increase in tertile of BMI in association with in-home solid fuel exposure.

Conclusions—This study suggests that in-home solid fuel exposure is associated with reduced lung function in an urban population.

Keywords

solid fuel; lung function; body mass index; Chinese

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Contributors

MSL and JQH participated in study design, statistical analysis and interpretation of the results, and wrote the manuscript. DCC originated study concept and design, advised analyses and interpretation of data, and revised the entire manuscript critically. FYZ, BYZ, LS, YZ, HLD, and HXZ collected data, analysis, and interpretation of data. All authors read and approved the final version of manuscript.

Competing Interests

The authors declare no potential conflicts of interest.

INTRODUCTION

The source of domestic fuels is changing rapidly, shifting from traditional to modern fuels such as natural gas. However, more than 50% of the world's population still uses solid fuels (mainly biomass and coal) for home for cooking and heating, contributing greatly to the burden of disease.¹⁻³

Epidemiologic evidence suggests that solid fuel exposure is associated with respiratory diseases such as acute respiratory infections (ARIs), chronic obstructive pulmonary disease (COPD), and lung cancer.⁴⁻⁷ One of the possible underlying mechanisms includes direct oxidative stress, induced by combustion by-products and indirectly via enhanced release of reactive oxygen species (ROS), and impaired ventilatory function.⁸ In addition to this imbalance of oxidative status, obesity, a central feature of the metabolic syndrome (MetS), can increase ROS production, since MetS is associated with elevated oxidative stress.⁹ The prevalence of MetS has increased in China significantly over recent decades with increasing body mass index (BMI).¹⁰ Although an association between indoor solid fuel exposure and impaired lung function is presumed, the interaction between household solid fuel exposure and BMI has not been examined.

We therefore performed a large-scale population-based study to assess the relation between exposure to household solid fuel, estimated by total amount and duration of exposure throughout the subjects' lives, and lung function. We also hypothesized that the effect of exposure to household solid fuel on lung function is greater among individuals with higher BMI. Modern China is facing an obesity epidemic, as are many other rapidly developing countries. At the same time, China remains as the world's largest consumer and producer of coal (Figure 1).^{11,12}

METHODS

Study Design and Data Collection

The Shanghai Putuo Cohort Study, a collaboration between the Harvard School of Public Health and Shanghai Putuo District People's Hospital, began recruiting subjects from August 2007 to July 2009 from Shanghai Putuo District in China. Detailed information regarding our study population has been reported previously.¹³ Briefly, study subjects were recruited from Shanghai Putuo District in China using random selection from census track data. Of the total 19,620 subjects, 15,183 provided written informed consent to participate in this study with the baseline clinical examination and questionnaire. Of these 15,183 subjects, 14,068 (71.7% of 19,630), aged 18 years and older, were included in this study. Of the 14,068 participants, 12,947 subjects had no missing data on spirometry. Finally, from the 12,947 subjects, individuals with missing covariates including education, height, smoking, pack-years of smoking, or second-hand smoke ($n = 441$) were excluded. Thus, a total of 12,506 (96.6% of 12,947) subjects were included in the analysis of solid fuel use and pulmonary function measures. Of the 12,506 subjects, participants with missing data on duration ($n = 59$) and total amount of solid fuel use ($n = 2,509$) were additionally excluded in the analysis. This left 12,447 subjects (96.1% of 12,947) for the final analysis of duration of solid fuel use and 9,997 individuals (77.2% of 12,947) for the final analysis of total amount and lifetime average amount of solid fuel use. Of the 12,506 participants, 9,750 subjects have ever used solid fuel for cooking and/or heating and 99% of 2,756 non-users use natural gas as a cooking fuel. Participants reported in jobs classified as white collar (41.4%), blue collar (7.0%), homemaker (1.9%), retiree (36.8%), others (12.5%), and missing (0.4%). 77.8% of participants are presently living in an apartment, or another type of house (22.1%) including 1 to 3 story houses, and missing (0.1%).

All participants were interviewed in person by trained personnel, using structured questionnaires. The questionnaires include socio-demographic factors (age, gender, education, marital status and household income), smoking history (smoking status, pack-years of smoking, and second-hand smoke), occupational history, and household fuel exposures. Individual household exposures to solid fuels (coal and biomass) were assessed in the questionnaire: ever use (yes or no), duration, total amount, and lifetime average amount. We did not assess current use or last use in the questionnaire but only access ever exposure in the past. Currently, the Putuo district home fuel supply is natural gas and no more biomass burning is allowed in the neighborhood. The assessment of duration of exposure (number of years for cooking/heating using solid fuels, year) was based on “How many years have you used coal as heating?” and “How many years have you used briquet, coal, or firewood for cooking?”. The assessment of annual amount (kg/year) was asked as “How many kilograms per year of this fuel have you used for cooking and heating?”. Based on these, we calculated the total amount (as calculated by multiplying duration of exposure by the annual amount of fuel used, kg) and the lifetime average amount of exposure (as calculated by multiplying duration by annual amount by dividing age, kg/year).¹³ These factors have been shown to influence the risk of lung cancer,^{14,15} but limited data are available with regard to their influence on pulmonary function in a population-based study. Anthropometric measurements such as height, weight, and waist circumference were taken during the physical examination. Body mass index (BMI) was calculated by dividing body weight in kilograms by the square of height in meters. Waist circumference was measured in centimeters at the mid distance between the top of the iliac crest and the bottom of rib cage. Trained personnel performed all measurements. The study protocol was approved by the Institutional Review Boards of the Harvard School of Public Health and the Shanghai Putuo District People's Hospital.

Spirometry

FVC and FEV₁ were measured by trained and supervised technician using a calibrated hand-held spirometers (Micro Plus, Micro Medical Ltd, Rochester, UK), which are portable and have shown to give good reproducibility,¹⁶ according to American Thoracic Society (ATS) guidelines.¹⁷ All testing was done in a sitting position. Intrasubject variability was assessed by coefficient of variation (CV), as calculated by SD/mean×100, of FVC < 20%, a criteria used for reliability in a large multicenter trial.¹⁸ The largest FVC and FEV₁ were recorded from at least three curves. FEV₁ and FVC were expressed in liters and also as the percentage of predicted values based on the prediction equations from the Chinese adult population.¹⁹ We computed correlation between the percentage of predicted values from published prediction equation from Chinese adult population¹⁹ and the percentage of predicted values from prediction equation from our sample. From this, we obtained coefficients of 0.97 for FEV₁ percent predicted and 0.93 for FVC percent predicted.

Statistical Analysis

All statistical analyses were performed using SAS version 9.2 (SAS Institute Inc., Carry, NC, USA). The primary outcome measures were FEV₁ percent predicted, FVC percent predicted, and FEV₁/FVC ratio. Household exposure to solid fuel for cooking and heating was expressed as the use of solid fuels during a lifetime (ever users versus nonusers), duration of exposure in years, total amount of solid fuel use in kilograms and lifetime average amount of solid fuel use in kilograms per year. This is done by assessing the exposure on a continuous scale and categorizing each into tertiles based on each exposure distribution. For FEV₁/FVC ratio, potential confounders such as age (years), gender, height (cm), education (less than high school, high school, and above college or more), second-hand smoke, smoking status (never, former, current), and pack-years of smoking were considered. For percent predicted values of FEV₁ and FVC, to avoid over adjustment, age

and height were not included because the percent predicted lung function parameters were already adjusted for age and height. Demographic and clinical differences between solid fuel users and nonuser groups were tested using the Chi-square test and *t*-test. Linear regressions were applied to estimate the adjusted regression coefficients (β), which represents a difference in the mean in solid fuel ever users compared to non-users, and the corresponding 95% confidence intervals (CIs) for the association between lung function measures and household solid fuel exposure.

To assess the linear trend in associations, trend tests were performed by categorizing the continuous exposure variables into tertiles and treating ordinal scores as continuous in regression models. To assess effect modification by BMI, multiplicative interaction terms along with the main effects were included in regression models.

RESULTS

The distribution of study population demographic characteristics stratified by household solid fuel use is shown in Table 1. The study population consisted of 5,847 men (47%) and 6,659 women (53%), with mean age of 48 years. Overall 3,479 (27.8%) were current or former smokers. The combined prevalence of overweight and obesity defined as BMI ≥ 25 was 26%. Of the 12,506 subjects, 9,750 (78%) participants were using solid fuels for cooking and heating in their home. Raw FEV₁ and FVC values were 2.7 and 3.0 L, respectively. Statistical differences between solid fuel users and nonusers were found in age, education, BMI, second-hand smoke, and smoking status. Lung function parameters (FEV₁ and FVC) were significantly lower in users compared to those in nonusers (mean of 96.6 versus 99.9 for FEV₁ percent predicted and 88.2 versus 94.6 for FVC percent predicted, respectively, $P < 0.001$).

The adjusted associations of household solid fuel exposure with FEV₁ percent predicted, FVC percent predicted, and FEV₁/FVC ratio are shown in Table 2. After adjusting for confounders, the subjects with exposure to household solid fuel had a 1.29% (95% CI 0.57 to 2.02) decrease in FEV₁ percent predicted and 3.46% (95% CI 2.74 to 4.18) decrease in FVC percent predicted, respectively, whereas no association was seen with FEV₁/FVC ratio. Compared to individuals in the lowest tertile of the duration, total amount, and lifetime average amount of solid fuel exposure, the highest tertile exposure group was associated with significant decreases in percent predicted FEV₁ and FVC, respectively (P value for trend < 0.001).

In a sensitivity analysis, we modeled the missing data for smoking as a separate category to check whether missing data in smoking cause bias our observed findings. The sensitivity analysis showed similar results as our main model: solid fuel ever users had a 1.29% (95% CI 0.58 to 2.00) decrease in FEV₁ percent predicted and 3.43% (95% CI 2.72 to 4.14) decrease in FVC percent predicted. Therefore, it is unlikely that our observed findings are due to possible bias by lack of data in smoking. In another sensitivity analyses that restricted data to only among never smoking population, we found an association between in-home solid fuel exposure and lung function: in-home solid users had a 0.73% (95% CI -0.07 to 1.54, $P = 0.07$) decrease in FEV₁ percent predicted and 3.1% (95% CI 2.29 to 3.92) decrease in FVC percent predicted. Compared with those in the lowest tertile of duration and total amount of exposure, participants in the highest tertile had greater decrease in FEV₁ percent predicted and FVC percent predicted among never smokers after adjusting for covariates (P values for trend < 0.001) (Appendix). For further sensitivity analysis, we additionally adjusted for BMI and found similar results: in-home solid fuel ever users had a 1.17% (95% CI 0.44 to 1.90) decrease in FEV₁ percent predicted and 3.22% (95% CI 2.50 to 3.94) decrease in FVC percent predicted, respectively. When we performed separate sensitivity

analysis with additionally adjusting for waist circumference, the number of subjects was reduced as 12,502 due to missing in waist circumference ($n = 4$) and the results showed similar results as our main model: in-home solid fuel ever users had a 1.20% (95% CI 0.47 to 1.92) decrease in FEV₁ percent predicted and 3.18% decrease (95% CI 2.46 to 3.90) in FVC percent predicted.

We observed significant effect modification by BMI in the association between solid fuel exposure and lung function parameters, after adjusting for confounders (Figure 2). Household fuel exposure was negatively associated with FEV₁ percent predicted and FVC percent predicted among subjects with the highest tertile of BMI (P -value for interaction is 0.004 for FEV₁ percent predicted, and is 0.003 for FVC percent predicted). We also assessed effect modification by BMI, as treated in four groups according to International classification by WHO [<18.50 (underweight), 18.50-24.90 (normal), 25.00-29.90 (overweight), and ≥ 30 (obese)]. We observed borderline significant effect modification by BMI in the association between solid fuel exposure and adjusted lung function parameters. Household fuel exposure was negatively associated with FEV₁ percent predicted and FVC percent predicted, respectively, among obese subjects with BMI ≥ 30 (P -value for interaction is 0.068 for FEV₁ percent predicted, and is 0.080 for FVC percent predicted).

DISCUSSION

In this large-scale population-based study, household solid fuel exposure was associated with reduced FEV₁ and FVC. We also observed larger decrements in lung function in association with greater amount and longer duration of exposure. Furthermore, the associations of solid fuel with lung function measures were stronger among subjects with higher BMI values than among non-obese subjects. These data suggest that obese people may experience a larger detrimental effect from household exposure to solid fuel than do non-obese people.

The mechanism for potential toxic effects of household solid fuels on lung function is still not completely understood, but one of the main mechanisms includes oxidative stress pathways. The burning of solid fuels emits multiple toxicants in gaseous and particle phases. Of specific concerns are household solid fuel-derived particulates including polycyclic aromatic hydrocarbons (PAHs) and metals, which are capable of promoting ROS and lung inflammation. It has been suggested that oxidative stress, as measured using lipid peroxidation indicator, is associated with impaired lung function in the general population.^{8,20} We could find no prior studies that examined the modifying effects of BMI as a key trait of metabolic syndrome in relation to in-home solid fuel exposure and pulmonary responses in the general population. Although the underlying mechanism is not clear, obesity may increase one's susceptibility to the adverse effects of particulate matter (PM), a major by-product from combustion of solid fuels, since lipophilic substances such as PAHs accumulate in adipose tissue. Recent animal study in rats showed that exposure to PM_{2.5} enhanced insulin resistance in a high fat diet rats.²¹ The magnitude of decline in lung function in response to short-term PM exposure was differential; two to five times higher among obese children than those of normal weight.²² In healthy adults, BMI was positively associated with exhaled nitric oxide, a marker of pulmonary inflammation.²³ More recent *in vivo* study shows that some toxic PAHs, such as benzo[a]pyrene, potentiate high fat diet effects on inflammation.²⁴ a key feature of metabolic disorders including obesity and diabetes.²⁵ Pro-inflammatory cytokines such as tumor necrosis factor- α (TNF- α) and other inflammatory mediators are over-expressed in the adipose tissue of experimental obese mouse models and in humans, suggesting a clear link in the development of chronic inflammation and metabolic syndrome.²⁶ Alternatively, it may also be possible that high ventilation in obese people may enhance the association between solid fuel exposure and

lung function. In healthy children, BMI was associated with an increase in the estimated total lung dose of deposited fine particles, suggesting that obese individuals may be associated with increased risk from inhaled ambient particles.²⁷

Recent epidemiologic data suggests that household air pollution from biomass fuel has been associated with respiratory diseases such as acute respiratory infections²⁸ in Asian countries where solid fuels for cooking and heating are used extensively. In a study by Regalado *et al.* (2006) conducted in the rural village of Solis, Mexico, they measured indoor concentrations of particulate matter (PM₁₀, particles with a diameter of 10 µm or less) in the kitchen when the cooking biomass stove was burning. They found significant decrease in FEV₁ (81 mL) and in FVC (122 mL) for women with a peak PM₁₀ concentrations higher than 2.6 mg/m³ compared with those with less than 2.6 mg/m³. However, little is known about other exposure indicators other than the type of fuel used in home, such as amount and duration of fuel use throughout lifetime, since these are important factor for characterizing indoor exposures when comparing developing and developed countries.⁵ In addition, whether obesity, a leading public health crisis, may have mechanistic implications for the pulmonary effects of household air pollution remains un-answered. To address these gaps in existing research, our community-based large population study found evidence that the use of solid fuel in the home had a pronounced effect on lung function in the overweight sub-population, implying a multiplier effect that makes obese individuals more susceptible to household air pollution effects.

In our study, household solid fuel exposure indicators do not have significant impacts on the FEV₁/FVC ratio. Because restrictive lung disease causes decreases in both FEV₁ and FVC, the FEV₁/FVC ratio can remain approximately normal (<http://meded.ucsd.edu/isp/1998/asthma/html/spirexp.html>). A recent longitudinal study among children aged 6 to 13 years living in Chinese cities reported that use of coal as a household fuel was associated with reduced growth rates of lung function, 33% and 39% of FEV₁ and FVC, respectively,²⁹ but they did not see significant association with FEV₁/FVC ratio, as consistent with our study, suggesting that indoor air pollution from household solid fuel use may cause mainly a restrictive pattern. Further study is needed to confirm the possibility that in-home solid fuel exposures cause pulmonary restriction.

Potential residual confounding by smoking may raise a concern. However, our sensitivity analyses performed in never smokers suggest that residual confounding by cigarette smoking may not explain the association between in-home exposure to solid fuel and lung function.

Despite the significance of this study, the findings need to be interpreted with caution. First, due to the cross-sectional design, we cannot rule out a possibility of reverse causation. However, we found consistent results with solid fuel exposures (duration and total amount), so this should be unlikely. Future research with a longitudinal approach would be important in confirming the association observed in this study. Second, household fuel exposure data were obtained by questionnaire, without personal monitoring measurements, so we do not know the precise levels of household fuel exposures. Although we estimated the total amount and duration of solid fuel used throughout life in the questionnaire based approach, more integrated approaches using qualitative and quantitative exposure assessments are needed for better assessing of individual's in-home fuel exposure and thereby identify household solid fuel-derived specific contaminants that play an adverse role in pulmonary function. Third, for assessing duration, total amount, and lifetime average amount of in-home solid fuel exposure, there is potential for measurement error due to recall based on questionnaire approach which may be particularly inaccurate in the older age group. Among solid fuel users, there was a positive correlation between age and duration of exposure ($r =$

0.724, $P < 0.0001$). When we analyze the association stratified by tertile of age (18-39, 40-55, and >55), significant decreases in percent predicted values of lung function measures in association with duration of solid fuel exposure were found among participants with 40 age 55 and age > 55 , but no association was found among subjects with lowest tertile of age. Generally, non-differential exposure misclassification can biases results toward the null. However, we observed greater effects of duration of exposure on lung function among participants aged > 55 and older. Therefore, it is unlikely that misclassification of exposure induce bias considerably. Possible selection bias due to lack of data on lifetime average amount of solid fuel use may raise concern. To check this, we analyzed the association between outcome and missing in lifetime average amount of solid fuel use among ever users. A decreased FEV₁ percent predicted was found among the subjects with missing data in lifetime average amount of solid fuel use compared with the subjects without missing, whereas an increase in FVC percent predicted was found among the subjects with missing data in lifetime average amount of solid fuel use compared with the subjects without missing. We thus may not completely rule out possible selection bias due to lack of data on lifetime average amount of solid fuel use. An additional limitation is that our regression models may not fully adjust for potential confounders, such as occupational exposure, although we were able to control for some important confounders, such as age, education, smoking, and pack-years of smoking.⁵ Possible effects of unmeasured confounders may need to be considered in future studies.

In conclusion, our analysis provides evidence that household fuel use may induce reductions in lung function in adults, particularly among obese subjects who may be more susceptible to in-home air pollution.

Acknowledgments

The authors gratefully acknowledge the contribution of all participants and the research team in Shanghai, and the research assistance of Ms. Marcia Chertok.

Funding

This study was supported by grants from the National Institute of Environmental Health Science [Grant ES000002]; and the National Institute for Occupational Safety and Health [Grant R010421]; and Shanghai Putuo District People's Hospital.

Abbreviations

ARI	acute respiratory infection
BMI	body mass index
COPD	chronic obstructive pulmonary disease
FEV₁	forced expiratory in 1 second
FVC	forced vital capacity
IQR	interquartile
MetS	metabolic syndrome
PM	particulate matter
PAHs	polycyclic aromatic hydrocarbons
ROS	reactive oxygen species
TNF-α	tumor necrosis factor- α

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What this paper adds

Few epidemiologic studies have examined the relation between household solid fuel use and lung function in an urban population, and none its potential effect modification by body mass index (BMI).

We found that exposure to household solid fuel is associated with reduced lung function, as indicated by forced expiratory volume in 1 sec (FEV₁) and forced vital capacity (FVC), in an urban population, and BMI modifies this association.

Our results underscore the importance of the control of exposure to solid fuel use at home and respiratory health surveillance, in particular among obese subjects who may be more susceptible to in-home air pollution.

Figure 1.

China's coal production and consumption and the prevalence (%) of overweight and obese (BMI ≥ 25 kg/m²) in Chinese adults. Based on data from EIA International Energy Annual (<http://www.eia.gov>) and the China Health and Nutrition Survey (CHNS) 1989-1997 (Du et al. 2002) and the 2002 China National Nutrition and Health Survey (Chinese Ministry of Public Health 2004, Wang et al. 2007). *Based on data from this study.

Figure 2.

Adjusted estimates (95% confidence interval) for FEV₁ percent predicted and FVC percent predicted associated with household solid fuel exposure by BMI (tertile, kg/m²). Each model was adjusted for education, second-hand smoke, smoking status, and pack-years of smoking. The regression coefficients (β) are indicated by the symbol and their 95% CIs by the solid lines. * $P < 0.001$.

Table 1General characteristics of the study population, stratified by solid fuel use, N (%) or mean $\pm$ SD

	Overall (N = 12,506)	Ever users (N = 9,750)	Nonusers (N = 2,756)	P-value [†]
Age, yrs				
18-29	2,078 (16.6)	756 (36.4)	1,322 (63.6)	<0.001
30-39	2,032 (16.2)	1,245 (61.3)	787 (38.7)	
40-49	2,048 (16.4)	1,734 (84.7)	314 (15.3)	
50-59	3,475 (27.8)	3,250 (93.5)	225 (6.5)	
60	2,873 (23.0)	2,765 (96.2)	108 (3.8)	
Gender				
Male	5,847 (46.8)	4,547 (77.8)	1,300 (22.2)	0.62
Female	6,659 (53.2)	5,203 (78.1)	1,456 (21.9)	
Education				
Less than high school	4,818 (38.5)	4,459 (92.6)	359 (7.5)	<0.001
High school	5,554 (44.4)	4,131 (74.4)	1,423 (25.6)	
College or above	2,134 (17.1)	1,160 (54.4)	974 (45.6)	
BMI				
<18.5 (underweight)	774 (6.2)	490 (63.3)	284 (36.7)	<0.001
18.5-25 (normal)	8,529 (68.2)	6,555 (76.9)	1,974 (23.1)	
25 (overweight and obese)	3,203 (25.6)	2,705 (84.5)	498 (15.6)	
BMI, kg/cm ²	23.1 $\pm$ 3.2	23.3 $\pm$ 3.1	22.2 $\pm$ 3.3	<0.001
Second-hand smoke				
Never	2,758 (22.0)	1,893 (68.6)	865 (31.4)	<0.001
Ever	9,748 (78.0)	7,857 (80.6)	1,891 (19.4)	
Smoking				
Current smoker	2,937 (23.5)	2,472 (84.2)	465 (15.8)	<0.001
Ex-smoker	542 (4.3)	503 (92.8)	39 (7.2)	
Never-smoker	9,027 (72.2)	6,775 (75.1)	2,252 (24.9)	
Amount of smoking, pack-years	6.6 $\pm$ 20.4	7.9 $\pm$ 22.2	2.3 $\pm$ 11.2	<0.001
Household solid fuel use				
Duration, yr	18.6 $\pm$ 15.1	23.9 $\pm$ 12.9	0	<0.001
Total amount, 1000kg	12.5 $\pm$ 12.4	17.3 $\pm$ 11.4	0	<0.001
Lifetime average amount, kg/year	231.6 $\pm$ 207.9	319.8 $\pm$ 177.5	0	<0.001
Lung function				
FEV ₁ , L	2.7 $\pm$ 0.8	2.5 $\pm$ 0.7	3.1 $\pm$ 0.8	<0.001
FEV ₁ , % predicted	97.4 $\pm$ 16.4	96.6 $\pm$ 17.0	99.9 $\pm$ 13.8	<0.001
FVC, L	3.0 $\pm$ 0.9	2.9 $\pm$ 0.8	3.5 $\pm$ 0.9	<0.001
FVC, % predicted	89.6 $\pm$ 16.7	88.2 $\pm$ 16.9	94.6 $\pm$ 14.7	<0.001
FEV ₁ /FVC ratio (%) [‡]	88.1 $\pm$ 7.8	87.7 $\pm$ 7.9	89.3 $\pm$ 7.1	<0.001

[†]P-value for comparing the difference between ever users vs. nonusers, given by Pearson chi-square test for categorical variables and *t*-test for continuous variables.

$$\frac{\dot{V}}{V}(\text{FEV}_1/\text{FVC}) \times 100$$

Table 2

Adjusted estimates (95% CIs) for percent predicted FEV₁ and FVC, and FEV₁/FVC ratio associated with household solid fuel exposures

	FEV ₁ % predicted [†]	FVC % predicted [†]	FEV ₁ /FVC ratio [‡]
Solid fuel use (N = 12,506)			
Nonusers	Reference	Reference	Reference
Ever users	-1.29 (-2.02 to -0.57)	-3.46 (-4.18 to -2.74)	0.16 (-0.22 to 0.53)
Duration, yr (N = 12,447)			
<10	Reference	Reference	Reference
10-24	-0.16 (-0.89 to 0.58)	-2.33 (-3.05 to -1.60)	0.75 (0.38 to 1.12)
24>	-2.35 (-3.13 to -1.58)	-5.90 (-6.66 to -5.13)	0.14 (-0.32 to 0.59)
P for trend test	<0.001	<0.001	0.686
Total amount, kg×1000 (N = 9,997)			
<4.00	Reference	Reference	Reference
4.00-16.75	-0.58 (-1.40 to 0.24)	-2.67 (-3.48 to -1.86)	0.69 (0.28 to 1.10)
16.75>	-2.17 (-3.02 to -1.31)	-5.58 (-6.43 to -4.73)	0.29 (-0.19 to 0.77)
P for trend test	<0.001	<0.001	0.304
Lifetime average amount, kg/year (N = 9,997)			
<81.8	Reference	Reference	Reference
81.8-340	-0.99 (-1.78 to -0.20)	-1.81 (-2.59 to -1.02)	-0.66 (-1.06 to -0.27)
340>	-1.17 (-2.01 to -0.33)	-3.44 (-4.27 to -2.60)	-0.01 (-0.43 to 0.42)
P for trend test	0.0008	<0.001	0.868

[†]Adjusted for education level (less than high school, high school, above college or more), second-hand smoke, smoking (current, former, never), and pack-years.

[‡]Adjusted for age, gender, height, education level (less than high school, high school, above college or more), second-hand smoke, smoking (current, former, never), and pack-years