Improvement in household stoves and risk of chronic obstructive pulmonary disease in Xuanwei, China: retrospective cohort study

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Abstract

Objective To test whether improvement in household coal stoves affected the incidence of chronic obstructive pulmonary disease (COPD) in Xuanwei County, China.
Design Retrospective cohort study (follow-up 1976-92) comparing incidence of COPD between groups with and without chimneys.
Participants 20 453 people born into homes with unvented coal stoves; 16 606 (81.2%) subsequently changed to stoves with chimneys.
Intervention Installation of a chimney in households in which unvented stoves had been used previously.
Results Installation of a chimney was associated with distinct reduction in the incidence of COPD. Compared with people who did not have chimneys, the Cox-modelled risk ratio (relative risk) was 0.58 (95% confidence interval 0.49 to 0.70, $P<0.001$) in men and 0.75 (0.62 to 0.92, $P=0.005$) in women. Modelled risk ratios were robust to different Cox model specifications. Relative risks decreased with time since stove improvement. In both sexes, the reduction in risk became unequivocal about 10 years after stove improvement.
Conclusions In Xuanwei, incidence of COPD decreased markedly after household coal stoves were improved.

Introduction

Burning coal and biomass fuels is the domestic energy source for almost 3 billion people.[1] The resulting smoke contributes importantly to the global burden of mortality, accounting for about 1.6 million of the 59 million deaths annually.[2 3] Indoor smoke is estimated as the eighth largest risk factor for global disease, accounting for 2.7% of disability adjusted life years lost (DALYs).[2 3] Exposure to smoke from solid fuel burnt indoors is strongly associated with an increased risk of COPD and other respiratory disorders.[4–10]

In Xuanwei County, Yunnan Province, China, rates of lung cancer were among the highest in China,[11] and rates of COPD were over twice the national average.[12] In Xuanwei >90% of residents are farmers.[13] For cooking and heating, residents usually burnt smoky coal (bituminous coal), smokeless coal (anthracite), or wood in unvented stoves. Unvented burning of smoky coal generates high concentrations of indoor air pollution.[11 14] In Xuanwei, rates of lung cancer[11 13] and COPD[12] are strongly associated with household use of smoky coal.

Most Xuanwei residents have changed from unvented stoves to stoves with chimneys. This greatly reduces indoor air pollution and was associated with a reduction in risk of lung cancer.[13] The effects on risk of COPD have not previously been documented, though we would expect that the incidence would decrease.[15] We compared incidence of COPD between people who installed chimneys and those who used only unvented stoves.

Methods

Data collection

We identified all farmers born 1917-51 who were living in Xuanwei's three central communes (the study area) on 1 January 1976 (31 364 farmers in all). From 1976-92, 1215 (3.9%) moved away and were not included in the analysis. From March-November 1992, trained interviewers administered a standardised questionnaire to the 30 149 remaining. They determined history of household stove and fuel use, diagnosed illnesses, smoking, cooking food, time spent indoors and outdoors, education, and residence. Participants were asked whether they had ever been diagnosed with chronic bronchitis or emphysema and, if so, the age and place of diagnosis. Chronic bronchitis and emphysema were combined into a single category of COPD. Dates of all deaths from 1976-92 were taken from death certificates. Informed consent was obtained from all respondents.

Data analysis

We restricted analysis to lifelong users of smoky coal (causing 2836 exclusions) and those who had used unvented stoves throughout their lives or who changed from unvented stoves to stoves with chimneys (5861 exclusions). We also excluded 999 people for other reasons (see bmj.com). Thus, the final dataset included 20 453 subjects (10 785 men and 9668 women), of whom 1487 (7.3%) had COPD and 16 606 (81.2%) had installed chimneys.

People left follow-up by reporting that they had received a diagnosis of COPD (integer age at diagnosis +0.5), if they died without COPD during follow-up, or if they were alive and free of COPD at interview in 1992.

There were 298 378 person years during follow-up (116 221 before installing a chimney and 182 157 after). We calculated incidence rates of COPD adjusted for age before and after installation. Product-limit survival curves, with incident COPD as outcome, were plotted by age for men and women with and without a chimney.

We used sex specific multivariable Cox models, with incident COPD as outcome (for details see bmj.com). We also assessed the change in incidence of COPD over time after installation of a chimney (see bmj.com for details).

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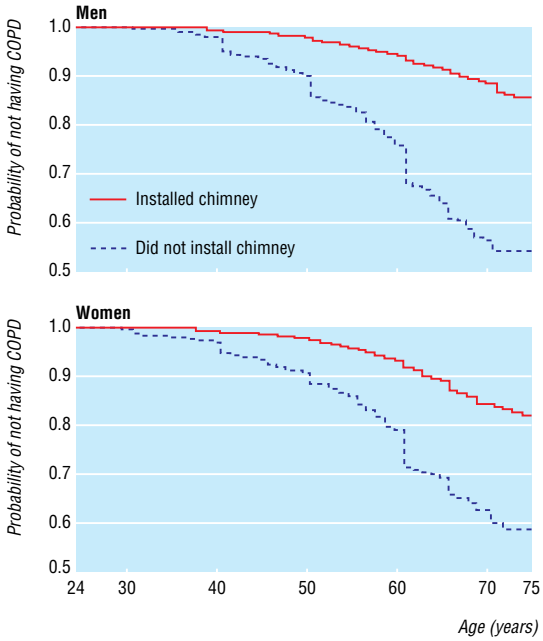

Product limit survival plots showing probability of not having chronic obstructive pulmonary disease (COPD) by age in years in men and women according to whether they had a chimney, Xuanwei, 1976-92

Results

For details of the participants see bmj.com. The age adjusted incidence rate of COPD was distinctly higher in people without chimneys than in those with chimneys, as was the overall mortality and mortality from COPD. The figure shows product limit curves of incidence of COPD in men and women according to stove improvement.

Using a stove with a chimney was distinctly and significantly associated with a reduction in the incidence of COPD (table) (see bmj.com). This reduction was more pronounced in men (42% reduction, $P<0.001$) than in women (25% reduction, $P=0.005$). In both sexes, living in a household of ≥ 5 people and spending ≥ 7 daily waking hours indoors up to the age of 20 were significantly associated with increased incidence of COPD. In men, smoking was significantly associated with increased incidence (modelled risk ratio 1.45 for ≥ 40 pack years, $P=0.007$ overall). In women, duration of cooking was not significantly associated with incidence.

The risk of COPD consistently decreased with length of time since installation of a chimney. In men and women who left follow-up within 10 years after installation, modelled relative risks were significantly higher than 1. This was observed until we excluded from analysis men and women who left follow-up within three and four years, respectively, after installation. Stove improvement was consistently associated with a highly significant reduction in incidence of COPD in people who left follow-up ≥ 10 years after improvement ($P<0.001$).

Discussion

We observed a substantial reduction in the incidence rate of COPD after installation of chimneys on household coal stoves in a rural province of China. The reduction in incidence was lower in women than in men, probably because a much higher proportion of women cook food and they start to cook at a much younger age and cook for longer, thus being exposed to more long term indoor air pollution at higher doses, both before and after installation of a chimney. Furthermore, even after installation, the average concentration of airborne particles ≤ 10 μm in diameter was still quite high near the stove (710 $\mu g/m^3$).[13]

Possible limitations

Our outcome variable was incidence rate of self reported diagnosis of COPD, and we did not compare these self reports with physicians' records. Though self reporting creates some uncertainty in the outcome and might bias results, we think this is unlikely (see bmj.com for details).

There was a long average interval of 12.8 years between reported age at installation of a chimney and the questionnaire interview. This is a source of uncertainty in data analysis. We emphasise, however, that the modelled overall effect would have been beneficial even in the presence of substantial error in reported age at installation.

COPD risk reduction over time

Risk of COPD was reduced unequivocally about 10 years after installation of a chimney but was higher just after improvement. The risk of COPD also tends to

Stratified main Cox model risk ratios (relative risks) for chronic obstructive pulmonary disease (COPD) incidence rate, by sex, Xuanwei, 1976-92

	Men*		Women*	
Independent variables	**Relative risk (95% CI)†**	**P value**	**Relative risk (95% CI)†**	**P value**
No stove improvement‡ *v* changed to stove with chimney	0.58 (0.49 to 0.70)	<0.001	0.75 (0.62 to 0.92)	0.005
<5‡ *v* ≥5 people in household	1.58 (1.33 to 1.88)	<0.001	1.57 (1.31 to 1.88)	<0.001
<7‡ *v* ≥7 waking hours/day indoors to age 20	1.34 (1.12 to 1.59)	0.001	1.82 (1.49 to 2.22)	<0.001
Used annual average ≤3‡ *v* >3 tonnes of fuel	1.14 (0.96 to 1.35)	0.136	1.01 (0.83 to 1.21)	0.960
Born in study area‡ *v* born outside study area	1.27 (0.62 to 2.59)	0.508	1.16 (0.92 to 1.47)	0.203
No education‡ *v* education	0.87 (0.74 to 1.02)	0.089	0.93 (0.74 to 1.18)	0.564
<3 rooms‡ *v* ≥3 rooms in home	1.01 (0.82 to 1.26)	0.901	0.93 (0.73 to 1.18)	0.527

*Men: 157 239.4 person years during follow-up (61 543.6 before stove improvement and 95 695.9 after it). Women: 141 138.1 person years (54 677.0 before stove improvement and 86 461.1 after it). Among the 116 220.6 person years before improvement, 41 466.4 (35.7%) were in people who never had improved stoves, and 74 754.2 (64.3%) were in people with improved stoves, but before they were improved.
†Likelihood ratio χ^2 statistics for both models were 157.2 (18 df, P<0.001) for men and 129.8 (16 df, P<0.001) for women. There were 792 diagnosed COPD cases in men (7.3%) and 695 in women (7.2%). The Cox models also included covariates for cooking food, smoking in men, and occupation in men (see bmj.com).
‡Reference category (relative risk=1).

What is already known on this topic

Chronic obstructive pulmonary disease (COPD) is a major component of the global burden of disease

Coal and biomass fuels are used for household cooking and heating by almost 3 billion people worldwide

Unvented burning of these solid fuels generates high levels of indoor air pollution and is strongly associated with increased risk of COPD and other diseases

What this study adds

In Xuanwei, China, the incidence of COPD decreased substantially after installation of chimneys on formerly unvented coal stoves (and consequent reduction of exposure to coal smoke)

be higher just after smoking cessation, presumably because some smokers quit only after becoming ill.[16–19] Similarly, some Xuanwei residents may have installed chimneys after the onset of respiratory symptoms. Also, it is conceivable that people who sought a physician's advice may have been more likely than others both to be diagnosed with COPD and to install chimneys. If so, people with chimneys could have been more likely to have had a diagnosis of COPD, and the present results could be conservative. In any event, the increase in risk just after improvement remains to be fully explained.

Summary and recommendations

We found a substantial reduction in the risk of COPD after installation of chimneys on coal stoves in Xuanwei. This has broad implications because unvented burning of coal and biomass fuels is widespread.[1] Findings may be especially important regarding biomass burning, which is more common than coal burning, because it is strongly associated with COPD[4–10] and because COPD accounts for more DALYs than lung cancer.[20] We expect that installation of chimneys would greatly benefit public health, especially in developing countries.

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Endpiece

The pleasure of existence

Does anyone ask, what constitutes the pleasure of existence? I answer, it consists of a pleasant and easy action of the stomach, and other organs immediately associated with it. Do any doubt the truth of the position? I reply, when the stomach is duly excited by food, by wine, by opium and by tea, the highest degree of corporeal, moral and mental happiness is enjoyed. It is by this state only, that the person feels social pleasure, or exercises, in perfection, the faculties of taste, judgement and reason. In this state only man delights in action and business, or reclines himself into rest and sleep.

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Submitted by Jeremy Hugh Baron, honorary professorial lecturer, Mount Sinai School of Medicine, New York