Association between biomass fuel and pulmonary tuberculosis: a nested case–control study

C Kolappan, R Subramani

Tuberculosis Research Centre, Chetput, Chennai, India

Correspondence to:
Dr C Kolappan, Tuberculosis Research Centre, Mayor V R Ramanathan Road, Chetput, Chennai-600 031, India; kola155@rediffmail.com

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ABSTRACT

Objective: To quantify the association between biomass fuel usage and sputum-positive pulmonary tuberculosis.
Methodology: A tuberculosis prevalence survey was conducted in a random sample of 50 rural units (villages) and three urban units in the Tiruvallur district of Tamilnadu, India during the period 2001–2003. Additional data regarding exposure to tobacco smoking, alcohol consumption, biomass fuel usage and Standard of Living Index (SLI) were also collected from the study participants. A nested case–control study was carried out in this population. Cases are defined as bacteriological-positive cases diagnosed by either sputum smear or culture examination. For each case, five age- (within ± 5 years of age) and sex-matched controls were selected randomly from the non-cases residing in the same village/unit. Thus, 255 cases and 1275 controls were included in this study.
Results: The unadjusted OR measured from univariate analysis for biomass fuel is 2.9 (95% CI 1.8 to 4.7). The adjusted OR measured from multivariate analysis using Cox regression is 1.7 (95% CI 1.0 to 2.9). Thirty-six percent of cases are attributable to biomass fuel usage.
Conclusion: The findings from this case–control study add to the evidence for an independent association between biomass smoke and pulmonary tuberculosis. Improvement in standards of living brought about by economic development will lead to more people using cleaner fuels for cooking than biomass fuel which in turn will lead to a reduction in the occurrence of pulmonary tuberculosis in the community.

Biomass fuel is any material derived from plants or animals which is deliberately burnt by humans. Approximately half the world's population and up to 90% of rural households in developing countries still rely on unprocessed biomass fuels in the form of wood, dung and crop residues.[1] In developing countries even where more sophisticated fuels are available, households often continue to use simple biomass fuels.

Many of the substances in biomass smoke can damage human health. The most important are particles, carbon monoxide, nitrous oxides, sulfur oxides, formaldehyde and benzopyrene.[2] Particles with a diameter of <10 μm and particularly those <2.5 μm in diameter can penetrate deeply into the lungs and appear to have the greatest potential for damaging health.[3] These pollutants from biomass smoke operate through different mechanisms. Particles <2.5 μm causes bronchial irritation, inflammation, increased reactivity, reduced mucociliary clearance, reduced macrophage response and reduced local immunity. The carbon monoxide binds to haemoglobin to form carboxyhaemoglobin which leads to diminished oxygen supply to vital organs including the lung. Nitrous oxides increase the susceptibility to bacterial and viral infections.[4]

Cigarette smoke, passive cigarette smoke and outdoor air pollution, which tend to produce lower exposures to pollutants than cooking smoke, have been linked to increased risk of tuberculosis. Both cooking smoke and cigarette smoke have been shown to cause immune suppression in laboratory studies. Such immunosuppression from exposure to cooking smoke may lead to greater susceptibility to infection and increased risk of progression to active tuberculosis in those who are already infected. In countries such as India, where a majority of people become infected with *Mycobacterium tuberculosis* in childhood, cooking smoke is likely to play a greater role in progression to disease. A systematic review of studies on association between indoor air pollution (biomass fuel smoke) and tuberculosis has reported that three studies showed positive association and two studies reported negative association.[5] There is need for further evidence on the association between biomass fuel and tuberculosis. The present study attempts to quantify the association between biomass fuel usage and sputum-positive pulmonary tuberculosis.

METHODS

The Tuberculosis Research Centre (TRC), Chennai, established a DOTS (directly observed treatment, short course) demonstration centre in May 1999 in a population of about 580 000 in the Tiruvallur district in south India. To assess the epidemiological impact of the DOTS strategy, a series of four disease prevalence surveys were proposed from 1999 onwards with an interval of 2.5 years between successive surveys. The disease survey was undertaken in a random sample of 50 rural units (villages) and three urban units. All persons in the selected villages/units were registered by door-to-door census, and all persons aged $\geqslant$15 years were screened by chest symptoms and chest radiograph (mass minioture radiography (MMR)). For those with an abnormal radiograph and/or chest symptoms, two sputum specimens (one spot and one overnight) were collected and examined by fluorescence microscopy and cultured on Löwenstein–Jensen medium. Cases are defined as bacteriological-positive cases diagnosed either by sputum smear or by culture examination.

During the second survey period (2001–2003), a total of 85 474 eligible persons were screened for pulmonary tuberculosis. Additional data regarding exposure to tobacco smoking, alcohol consumption, biomass fuel usage and Standard of Living

Index (SLI) were available for 52 488 of these persons. By tradition and native culture, the women in the study area neither smoke nor consume alcohol. In this rural culture it is considered impolite to ask women about their smoking and alcohol habits. The prevalence of tobacco smoking among women in India is very low (0.4%),[6] as is the prevalence of alcoholism among females in South India (<1%).[7] The collection of data on exposure to tobacco smoking and alcohol consumption was therefore restricted to the male population. All females were considered to be non-smokers and non-alcohol users.

All male participants were interviewed at the time of *x* ray examination, using a questionnaire to collect information such as exposure to smoking and alcohol use, age at which the behaviour started, duration of the habit, average consumption per day (number of cigarettes/beedies or quantity of alcohol in millilitres), and entered in a pre-coded format. A smoker was defined as any person who had ever smoked any type of tobacco product at any time prior to the date of interview. In other words, a smoker is a person who has a history of smoking in the past and/or is smoking currently and is different from a non-smoker. An alcohol user was defined as any person who had ever consumed any type of alcoholic liquor at any time prior to the date of interview. In this predominantly rural study population, country liquor is consumed habitually by the rural men folk. There are hardly any casual drinkers among them. A person is either a habitual drinker or a non-drinker. Similarly the data on the type of cooking fuel used in the households were collected from the head of the family in each household. The households were classified on the basis of type of fuel used as biomass, non-biomass and biomass plus non-biomass households. Biomass fuel is any material derived from plants or animals, which is deliberately burnt by humans. Rural households use unprocessed biomass fuels in the form of wood, dung and crop residues. Non-biomass fuels are fuels such as kerosene, LPG (liquefied petroleum gas) and electric stoves.

Data on SLI (a measure of socioeconomic status) were available for cases and controls from an independent study.[8] This independent study assessed the standard of living using a semi-structured, precoded, pretested questionnaire. The interview included household identification, demographic characteristics, number of household members who were earning, income, assets and particulars of their standard of living. The SLI was calculated using the National Family Health Surveys (NFHS) criteria.[9] On the basis of these criteria the survey population was categorsed into low SLI, medium SLI and high SLI groups.

Nested case–control study

A nested case-control study was carried out in this population to study the association between biomass fuel usage and pulmonary tuberculosis. A total of 257 bacteriological-positive cases were diagnosed and 255 of them were included in this study. (For two cases suitable controls were not available.) An individual whose sputum was either positive for AFB (acid-fast bacteria) by smear microscopy or positive for *M tuberculosis* by culture examination was defined as a bacteriological-positive case of pulmonary tuberculosis.

Selection of controls

For each case, five age- (within ±5 years of age) and sex-matched controls were selected randomly from the non-cases residing in the same village/unit. Thus, 255 cases and 1275 controls were included in this nested case–control study.

The ethics committee of the TRC approved this study and informed consent was obtained from all the participants in the study.

Statistical analysis

The data on the variables age, sex, smoking, alcohol use, biomass fuel usage and SLI were available for all the cases and controls. Since age and sex were matched for cases and controls, the univariate analysis was restricted to the remaining four variables only. The multivariate analysis was done by using a Cox regression model, stratifying by the pairwise matching variable to obtain the adjusted odds ratio (OR) with 95% CI and the attributable risk by the fit of the model (R^2) with and without biomass fuel estimated using SPSS version 13.0 (Chicago, Illinois, USA)

The attributable proportions for the risk factors were estimated as follows:

$$\frac{P\,(OR-1)}{P\,(OR-1)+1}$$

Where P is the prevalence of exposure among controls and OR is the adjusted OR.

RESULTS

The study population consisted of 255 cases (221 (87%) males and 34 (13%) females) and 1275 controls (1105 males and 170 females). The male female ratio was 6.5:1. Among the 255 cases, 92 (36.1%) belonged to the 15–44 year age group, 94 (36.9%) were from 45–59 year age group and 69 (27%) were aged ⩾60 years.

Table 1 shows that 51% of cases and 39.2% of controls were smokers; 35.7% of cases and 26.6% of controls were alcohol users; and 90.6% of cases and 80% of controls were exposed to biomass fuel smoke. Among cases, 40, 38 and 22% belonged to the low, medium and high SLI groups, respectively. Similar figures for controls were 23.8, 33.3 and 43%, respectively.

The distribution of cases and controls by households was as follows: one case each from 247 households; one control each from 1213 households; one case and one control from 6 households; 2 cases from one household and 2 controls from 28 households.

The unadjusted ORs (univariate analysis) and the adjusted ORs (multivariate analysis) using the Cox regression model for smoking, alcohol use, biomass fuel and SLI are shown in table 1. The unadjusted ORs and 95% CI were 1.8 (1.3 to 2.4) for smoking, 1.7 (1.2 to 2.3) for alcohol use, 2.9 (1.8 to 4.7) for biomass fuel, 2.4 (1.7 to 3.5) for medium SLI and 3.6 (2.5 to 5.3) for low SLI. The adjusted ORs and 95% CI were 1.4 (1.0 to 2.0) for smoking, 1.3 (0.9 to 1.8) for alcohol use, 1.7 (1.0 to 2.9) for biomass fuel, 2.0 (1.4 to 2.9) for medium SLI and 3.0 (2.0 to 4.4) for low SLI.

Table 2 shows the attributable proportions for the risk factors smoking, alcohol use, biomass fuel and medium and low SLI. It shows that 14% of cases are attributed to smoking and 36% of cases are attributed to biomass fuel usage. The attributable risk estimated by the fit of the model (R^2) with and without biomass fuel was 0.0374 and 0.0358, respectively.

DISCUSSION

In this nested case–control study, cases and controls were selected from a prevalence survey. All cases were confirmed

Table 1 Results of univariate and multivariate analysis of risk factors for tuberculosis

Sex: both sexes			Univariate		Multivariate	
Variable	Case	Control	OR (95% CI)	p Value	OR* (95% CI)	p Value
Smoke						
Non-smoker	125	774	1.0		1.0	
Smoker	130	501	1.8 (1.3 to 2.4)	<0.001	1.4 (1.0 to 2.0)	0.043
Alcohol use						
Non-user	164	936	1.0		1.0	
User	91	339	1.7 (1.2 to 2.3)	0.002	1.3 (0.9 to 1.8)	0.165
Household SLI						
High	56	548	1.0		1.0	
Medium	97	424	2.4 (1.7 to 3.5)	<0.001	2.0 (1.4 to 2.9)	<0.001
Low	102	303	3.6 (2.5 to 5.3)	<0.001	3.0 (2.0 to 4.4)	<0.001
Cooking fuel						
Non-biomass	24	252	1.0		1.0	
Biomass	231	1023	2.9 (1.8 to 4.7)	<0.001	1.7 (1.0 to 2.9)	0.040

*Adjusted ORs obtained by Cox regression stratifying by the pairwise matching variable.
SLI, Standard of Living Index.

bacteriologically. Cases included smear-positive subjects and smear-negative culture-positive subjects. As the survey employed active case-finding methodology, the majority of the cases were smear-negative culture-positives who are less infectious than the smear-positive cases. For each case, age- and sex-matched controls were selected randomly, from non-cases in the same neighbourhood (village/urban unit), to minimise the possibility of selection bias. The efficiency of the study design is improved by selecting five controls for each case. Similarly, the information bias was also minimised by collecting the exposure data on smoking, alcoholism and biomass fuel at the time of screening the survey population for tuberculosis by chest *x* ray (MMR), at which point the disease status of the individuals interviewed was not known. There is also no possibility of recall bias as the exposure data were collected prior to the diagnosis of cases. The households using both biomass and non-biomass fuels were considered as biomass households during the analysis, which might have underestimated the effect of biomass fuel. However, the number of such households was very small.

Since age and sex are known risk factors for pulmonary tuberculosis,[10] their confounding effect on the other risk factors was controlled by matching the cases and controls for age and sex. The confounding effect of the risk factors smoking, alcohol use, biomass fuel and SLI on one another was controlled by multivariate statistical analysis.

Our study results show that biomass has a stronger association (OR 1.7) with pulmonary tuberculosis than smoking (OR 1.4) but weaker than medium SLI (OR 2.0) and low SLI (OR 3.0). An earlier report from a study on 200 000 Indian adults showed an association between self-reported tuberculosis and exposure to wood smoke with an OR of 2.6 (1.98 to 3.37) after adjustment for a range of socioeconomic factors only, but not for smoking and alcohol use.[11] Another study from north India reported an association (OR 2.5) between the use of biomass fuel and tuberculosis defined by clinical measures, although adjustment was made only for age.[12]

It is clear that tuberculosis is a social disease since it is more prevalent among poor people living with malnutrition in overcrowded communities such as urban slums. Socioeconomic status is an important risk factor for pulmonary tuberculosis. Mainly people with a low standard of living use biomass fuel. In this study we have used a composite measure of socioeconomic conditions called the SLI. In fact, low and medium SLI have the highest risk in this study. However, biomass still has an independent association with tuberculosis, which is larger than the risk associated with tobacco smoking and alcohol use.

Another interesting finding in this study is that 36% of the tuberculosis cases can be attributed to biomass fuel as compared with 14% of cases attributed to smoking. This finding will have substantial implications for public health, especially when 52% of the world population uses biomass fuel for cooking.[13]

Women are exposed directly to the biomass smoke while cooking, but men who are less exposed to biomass smoke have a much higher prevalence of tuberculosis. This may be due to contact with more people in society and habituation to tobacco smoking and alcohol use.

Table 2 Attributable proportions for the risk factors

Risk factors	P	OR	P (OR −1)	P (OR −1)+1	Attributable proportions (%)
Smoking	0.39	1.4	0.16	1.16	14
Biomass fuel	0.8	1.7	0.56	1.56	36
Medium SLI	0.33	2	0.33	1.33	25
Low SLI	0.24	3	0.48	1.48	32

P, prevalence of exposure; SLI, Standard of Living Index.

Limitations

There are two limitations. First, the exposure to cooking smoke was not quantitatively measured. Secondly, the study population did not include children up to the age of 14 years. The effect of biomass smoke on childhood tuberculosis, especially mother to child transmission of tuberculosis, could not be studied.

CONCLUSION

This study shows that biomass used as a cooking fuel is an independent risk factor for pulmonary tuberculosis. Usually people with a low or medium standard of living use biomass fuel. Standard of living includes economic status, overcrowding, housing type and assets. Improvement in the standard of living brought about by economic development will lead to more people using cleaner fuels for cooking than biomass fuel which in turn will lead to a reduction in the occurrence of pulmonary tuberculosis in the community.

Policy implications

The finding from this study that biomass as a cooking fuel is a risk factor for pulmonary tuberculosis implies that tuberculosis occurrence can be reduced substantially by lowering or preventing exposure to cooking smoke from biomass fuel. Ideally the policy should be to promote the use of cleaner fuels wherever biomass fuels are currently used. However, in practice, with the existing infrastructure and fuel availability, it is not possible to provide clean fuels to all households in the country. A more practical approach will be to promote improved cooking stoves. Inexpensive biomass burning stoves that are fuel-efficient, less smoky and designed to prevent the release of pollutants indoors should be made available.

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