

studies included in this meta-analysis in terms of design, dealing with confounders, calculating risk with different comparator groups and exposure assessment. All these factors added substantial statistical heterogeneity between different studies that might have influenced the risk estimate. Almost all the studies of COPD considered populations over the age of 35 years which might increase the effect size as the prevalence of COPD increases with age and is highest among the elderly.²⁸ There was variation in the assessment of exposure, most studies not measuring exposure directly, instead using proxy measurements such as the number of hours spent doing cooking or the presence or absence of room ventilation. This lack of direct measurement could have resulted in either overestimation or underestimation of effect, always assuming that current measurement (which, when obtained, is usually measured for a period of ≤ 24 h) truly represents long-term exposure which is more relevant in the development of COPD.

The pooled estimate of chronic bronchitis for different types of fuel showed similar results to that of COPD, identifying wood smoke (OR=2.64, 95% CI 2.12 to 3.29) as the most important risk factor, followed by mixed biomass smoke (OR=2.46, 95% CI 1.78 to 3.39). The studies relating to chronic bronchitis used respiratory questionnaires (mostly the British MRC questionnaire): studies which did not use validated questionnaires were excluded from the meta-analysis. Reporting and recall bias cannot be ruled out in questionnaire studies. People in developing countries consider wheeze, breathlessness and bringing up phlegm to some extent as normal, which will probably result in under-reporting of symptoms²⁹ and, if this is differentially expressed between exposed and non-exposed groups, this may influence the true risk. Bias might also have occurred in these studies due to use of terminology. Some words such as "wheeze" do not have an equivalent word in many languages. Further, in some parts of the world, people are reluctant to provide personal information, especially regarding health, because of social taboos, especially an issue in southern Asia. Finally, the review was limited by only including studies in English, which might have resulted in publication bias.

In LEDCs, a family switching from one fuel to another is quite common. Many individuals in urban areas who currently use cleaner fuel may, in earlier years, have used solid fuel for cooking. This might have resulted in a residual effect in the control group, so information on past fuel use should be gathered in such studies.

Publication bias was shown in studies of COPD using the lung function criterion showing higher effects in studies which were conducted before 2000. This might relate to study design issues which were not explicit in the described methodology, such as approaches to recruitment, level of training of technicians performing spirometry, differences in use of bronchodilators in assessing COPD or inconsistent use of or lack of calibration of lung function equipment. For both COPD and chronic bronchitis, inadequate allowance for confounders such as exposure to outdoor air pollution or to toxic substances such as pesticides (most rural dwellers are farmers or housewives) or inadequate assessment of cigarette smoke exposure whether active or passive may have resulted in biased results. Finally, the heterogeneity could be real, one explanation being differential toxicity of the smoke from different biomass fuels.³⁰

No studies provided information to construct a dose-response function. This should be regarded as an important aim as a simple linear relationship as is seen in studies of outdoor air pollution is unlikely to hold for exposures as high as those recorded in these studies. Determining the shape of the dose-response curve will inform on the levels to which exposures need to be reduced to

Box 1 Inclusion criteria for the systematic review

1. English language only.
2. Papers contained original data and were full-length peer-reviewed reports of cohort, case-control or cross-sectional studies.
3. Data for a non-exposed comparator group were provided.
4. Adjustment for confounding by smoking was addressed.
5. Contained quantitative effect estimates of the associations between exposed and non-exposed group to biomass/solid fuel or data sufficient to calculate effect estimate.
6. Had an adequate sample size.
7. Had used standard questionnaires or well reported questions to measure the respiratory symptoms for chronic bronchitis.
8. Lung function measured according to American Thoracic Society criteria.

have a significant impact on health, and this may vary for different fuels given the heterogeneity by fuel use shown in this analysis.

Future studies need to be designed to include all the important risk factors, especially some form of measurement of direct exposure to biomass smoke. What such a measurement should be is as yet undetermined, but, for the moment, 24 h mean exposures (as are used in studies of outdoor air pollution exposure) should be regarded as the most appropriate.² Confounders such as environmental tobacco smoke exposure, occupational exposure to dusty environments and smoking status should all be considered. Fuel use history should be recorded accurately to allow life-course exposure to biomass fuel smoke to be modelled or estimated to enable determination of any residual effect of previous solid fuel smoke exposure. Health outcomes should be measured by validated instruments (whether lung function equipment used by well-trained technicians or questionnaires) with clearly defined and agreed protocols adhering to standard criteria.

CONCLUSION

Despite heterogeneity in design, measurement and quantitative effect estimates among the studies included in this meta-analysis, consistent evidence was found that exposure to indoor air pollution is a risk factor for COPD and chronic bronchitis, with at least a doubling of risk, although with marked heterogeneity by both country and fuel type. At present there is insufficient information to define a dose-response relationship, and there are no epidemiological studies which have considered potential differential toxicity for different fuel types, although this analysis shows a gradient of effect by fuel, with wood smoke being associated with the greatest effect. Future studies should address these study design issues to improve the risk estimates for exposure to different fuel types.

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