RESEARCH ARTICLE

Association between choice of cooking fuel and peak expiratory flow rate among rural women in the Niger Delta, Nigeria [version 1; peer review: 1 approved, 1 approved with reservations]

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Abstract

**Background:** Long-term exposure to indoor air pollution from biomass fuel combustion is a risk factor for respiratory disease, which is an increasingly prevalent contributor to morbidity and mortality in low- and middle-income countries. This study evaluated the association between household fuel use and the peak expiratory flow rate (PEFR) of rural-dwelling women in selected communities of the Niger Delta.

**Methods:** This was a cross-sectional study including 321 non-smoking women aged 18 years and older. Questionnaires were used to obtain data on predominant fuel used and a brief medical history. Women with current respiratory symptoms were excluded. Fuel use was classified into three categories: biomass fuels (BMF), such as wood, animal dung and coal, kerosene and liquefied petroleum gas (LPG). The PEFR was measured with an Omron peak flow meter using standard protocols and was abnormal if it was less than 80% of predicted value based on age and height.

**Results:** The mean age of the 321 women was 38.5±14.2 years. The biomass fuel users had significantly lower PEFR (353.9±104.4) compared to kerosene users (376.2±70.1) and LPG users (393.6±93.3) (p=0.030). The overall prevalence of abnormal PEFR was 22.4%. The PEFR was abnormal in more BMF users (28%) than kerosene users (13.4%) and LPG users (9.4%) (p=0.005). The PEFR of women who used LPG was 20.8 l/min higher than BMF users (p=0.012). The users of BMF were 5.8 times more likely to have abnormal PEFR than LPG users (OR 5.8, 95% CI 1.62, 20.52, p=0.007).

**Conclusion:** In this population, the use of biomass fuel was significantly associated with abnormal PEFR. This needs to be further explored in this population with a larger study using more objective measures, such as spirometry testing, to guide policies for the implementation of preventive strategies to protect vulnerable women from chronic obstructive airway disease.

**Keywords**

Biomass fuel, Air pollution, Pulmonary function, Peak Exploratory Flow Rate
Introduction
According to the World Health Organisation, around 3 billion people around the world use kerosene, biomass (wood, animal dung and crop waste) and coal as domestic fuels. Their incomplete combustion produces harmful pollutants. These pollutants have adverse effects on both human health and the climate1. Around 20% of black carbon emissions globally result from traditional solid fuel stoves and open cooking fires, especially when biomass is the fuel source2. In low- and middle-income countries in Africa and Asia, household solid fuel use contributes 60–80% of black carbon emissions, while kerosene use contributes 270 Gg of black carbon annually3. Products of incomplete combustion like black carbon and methane contribute to climate change, while carbon monoxide, Sulphur dioxide, nitrous oxide and particle mass with aerodynamic diameter less than 2.5 μm (PM2.5) have been linked to adverse health outcomes including cardiovascular disease, respiratory diseases and lung cancer4. In 2015, ambient PM2.5 was the fifth leading risk factor for global mortality4. Over the last several decades, the prevalence rates of chronic obstructive pulmonary disease (COPD) and asthma have steadily risen and research has shown links with ambient air pollution5. Air pollution occurs outdoors and indoors, but the majority of air pollution occurs indoors especially in developing countries where it is predominantly linked to combustion of biomass fuels for domestic purposes like cooking, heating or lighting6. The World Health Organization estimates that 3.8 million people die yearly from illnesses attributable to indoor air pollution resulting from the use of these fuels7.

The use of biomass fuel is prevalent around the world as it used by over half of the world’s population7. Any animal or plant material that is burned by humans for energy is referred to as biomass fuel, but wood is the most common form of biomass fuel used around the world and in rural parts of Nigeria. Up to 70% of households in Nigeria use biomass fuels and this is more prevalent in the rural (86%) compared to the urban areas (42%)8. A survey of households across eight states in Nigeria in 2002 showed that 94.2% and 57.4% of households in rural and urban areas, respectively, employ the use of solid biomass fuels as their main source of fuel for domestic purposes8. Kerosene is second only to biomass fuel as the most common fuel source in rural communities. This is not a “clean” fuel as combustion of kerosene also releases harmful air pollutants although less than is released when biomass fuel is combusted and its use has been linked to adverse effects on lung function9.

Women and children in developing countries are the most exposed to harmful air pollutants released during fuel combustion, as traditionally women bear the responsibility for cooking and usually have their children around them. Exposures to these air pollutants have been shown to contribute to diseases of the respiratory system via various mechanisms, including airway inflammation and direct oxidant damage to cell membranes. This leads to increased susceptibility to acute respiratory infections, chronic bronchitis, bronchial asthma, chronic obstructive pulmonary disease, tuberculosis and even possibly lung cancer10-17. Although cigarette smoking is the most important risk factor for COPD, it is estimated that 25% of premature deaths from COPD in low- and middle-income countries are due to household air pollution1. This health risk caused by daily smoke exposure is preventable.

The peak expiratory flow rate (PEFR) is an inexpensive method to evaluate lung function and can be applied in epidemiologic settings. It is a measure of large airway caliber and it corresponds to the maximum flow achieved during a forced exhalation starting from the level of maximal lung inflation. It requires a simple hand-held device that is readily available and the procedure can be learnt even by young children18. Spirometry is the gold standard for diagnosis of airway diseases however in rural areas with limited resources, the PEFR assessment is a more practical measure of assessment. Moreover, PEFR done with good effort correlates with the forced expiratory volume in one second (FEV1) measured by spirometry, and studies have shown a correlation between PEFR and mortality from respiratory diseases especially COPD19 as well as with indicators of general physical and cognitive health20-22.

The normal value of PEFR for adults varies based on height, gender, race and respiratory effort among other variables. A study published in Nigeria estimated that the mean value for PEFR for healthy Nigerian women (average age 29.4 years) was 385.6 L/min (±65.7). This is lower than average Caucasian values20. However, not enough is known about the associations between fuel type use and PEFR in rural women in the Niger Delta region of Nigeria.

In this study, we thus sought to assess the peak expiratory flow rate as a measure of lung function among a cross section of rural dwelling women in Niger Delta Nigeria and examine any association with the type of cooking fuel used.

Methods
Study design
This cross-sectional study is part of a larger study to evaluate the extent and impact of indoor air pollution from biomass fuel use for domestic purposes among rural women in southern Nigeria.

Study setting
Rivers State is one of the 36 States in Nigeria, it is in the south-south geopolitical zone and currently has 23 local governments, occupying an area of 1,077 km², with a population of 5,198,716 people24. The main economic activities are fishing, agriculture and crude oil exploration. It is a region beset with environmental challenges, ranging from air pollution from natural gas flaring activities to massive water and land pollution from crude oil exploration activities. Added to this are the fact that much of the state is underdeveloped, with high levels of energy poverty (83.1%) causing a significant proportion of the population to use mostly firewood, sawdust and other crude forms of fuel for cooking purposes25. There are 23 Local Government Areas (LGAs) in Rivers state and one (Abua/Odual) was purposely selected because it is a predominantly farming community with ample access to biomass (predominantly wood) for fuel use. Its population is estimated at 282,410.
Sample size and sampling
A sample size of 328 individuals was calculated using the formula for descriptive cross sectional surveys, with a 95% confidence level, 6% precision, prevalence of 43.3% abnormal PEFR among women using biomass fuel in a previous study, with a 20% mark-up for non-response. Sampling was done in two stages. In the first stage, simple random sampling through balloting was used to select three communities: Omelema, Emilaghan and Ogbema from the nine communities in the LGA. In the second stage 110 households were sampled per community using systematic sampling method. The first household was selected by simple random sampling and then subsequently next households were sampled based on a sampling interval calculated by dividing the total number of households in each community by 100 households. Where selected households did not have eligible participants, the next household was selected. Study participants were recruited and interviewed using a structured questionnaire in their homes.

Ethical statement
Ethical approval for the study was obtained from the ethics committee of the University of Port Harcourt and the Primary Health Care Management Board of Rivers State. The study was carried out in keeping with the Helsinki Principles for human research. Participants either signed or thumb-printed a consent form. The purpose of the study was explained and relayed in the local language for those who did not understand English. The participants were reassured that the data collected was confidential and anonymised. The participants were informed of their freedom to refuse or withdraw participation at any time with no negative consequences.

Study population and procedures
This was a household survey that employed a cluster sampling method to recruit females aged ≥18 years who were full-time residents and were the principal cooks in their households and gave informed consent. Other inclusion criteria included no history of active or passive cigarette smoking, no current symptoms of respiratory disease (breathlessness, cough or wheezing), no cardiac or other illness of note.

Six trained research assistants collected information on socio-demographic variables, predominant fuel used for domestic purposes (biomass, kerosene or liquefied petroleum gas) and a brief medical history using a questionnaire.

Physical measurements taken included weight, height, and blood pressure. Weight was measured with a Seca mechanical weighing scale to the nearest 0.5 kg with the subject wearing only light clothing, and height was measured using a flexible tape measure held against a straight wall. The participant was asked to stand with their feet together without shoes or head gear, back and heel against the wall and the reading was taken to the nearest 0.5 cm. Body mass index was calculated as body weight in kilograms divided by the square of the height in meters and classified according to the WHO criteria as normal weight (18.5-24.9 kg/m²), overweight (25–29.9 kg/m²) or obese (more than 30.0 kg/m²).

Blood pressure was measured with validated automatic Omron M5 BP monitors (Omron Corp, Tokyo, Japan) with an appropriate cuff size on the patients’ right arm in the seated position with feet on the floor after a 5-minute rest. The average of two blood pressure measurements taken 5 minutes apart was used.

PEFR was assessed using OMRON Peak Flow Meters (PFM20). The peak flow rate was measured with the subjects in standing position without a nose clip and holding the peak flow meter horizontally. A tight-fitting disposable cardboard mouth-piece was inserted into the inlet nozzle for every subject and the pointer was at zero. They were asked to place their lips tightly around the mouthpiece. The subjects were asked to take a deep breath and exhale as hard and fast as possible in a single blow into the instrument. The procedure was repeated thrice with an interval of half a minute between each attempt and the result of each attempt was recorded in liters per minute. The best of the three readings was recorded. Predicted PEFR was calculated on the basis of age in years and height in centimeters as 3.310*height (cm) – 1.865*age (years) – 81.0. Abnormal PEFR was defined as patient’s observed PEFR less than 80% of the predicted.

Statistical analysis
This was performed with Statistical Package for the Social Sciences, version 21.0 (SPSS Inc., Chicago, IL, USA). Continuous variables were expressed as mean (standard deviation) and categorical data as proportions and percentages. The outcome variables of interest were PEFR and PEFR category (abnormal PEFR was defined as <80% of predicted PEFR). These variables were compared between the three fuel use groups users using ANOVA with post-hoc LSD and Chi squared tests. Association between the type of fuel used and PEFR was assessed with linear regression with the latter as the dependent variable. Logistic regression analysis was used to determine the odds of a study participant being classified as having abnormal PEFR by fuel use category. The analyses were adjusted for confounding variables. P-values less than 0.05 were considered statistically significant.

Results
Demographic characteristics
The study participants included in the study were the 321 women (response rate, 97.8%) who had optimal peak flow meter measurements. The mean age of the study population was 38.5 ± 14.2 years. The most prevalent fuel used was BMF, which was used as the predominant fuel source by 207 women (64.5%). This was followed by kerosene (82 women, 25.5%) and liquefied petroleum gas (LPG) (32 women, 10.0%). The predominant occupation was farming (161 women, 50.2%), followed by trading (81 women, 25.2%); 42 women (13.1%) were students/unemployed and 37 (11.5%) were skilled workers. Raw data for this study are available on Open Science Framework.

General characteristics of the participants stratified by type of fuel used
The users of BMF were significantly older than users of kerosene or LPG. A majority of the study participants had
secondary-level education, with no significant difference in educational attainment among the groups. The predominant occupation in all groups was farming and there was no significant difference in occupation category among the groups. Kerosene users had the highest prevalence of poorly ventilated kitchens and family history of respiratory disease. Biomass fuel users were significantly older, shorter, had higher SBP and lower PEFR compared to the other two groups (Table 1).

Association between type of fuel used and peak expiratory flow rate
The biomass fuel users had significantly lower (values given as mean ± standard deviation) PEFR (353.9±104.4) than kerosene users (376.2± 70.1) and LPG users (393.6±93.3) and this was statistically significant (p= 0.030). The overall prevalence of abnormal PEFR was 22.4%; 28% of biomass fuel users, 13.4% of kerosene users and 9.4% of LPG users had abnormal PEFR. This was also statistically significant (p=0.005) (Table 2).

In logistic regression, predominant use of biomass fuel compared to LPG, significantly increased the odds of abnormal PEFR (OR 5.8, 95% CI 1.62, 20.52, p=0.007) after adjusting for confounding variables (age, height, weight, poor kitchen ventilation, time spent cooking per day and family history of respiratory disease). Kerosene use also increased the odds of having an abnormal PEFR, but this was not statistically significant (Table 3).

Discussion
In this population of rural women in Niger Delta, Nigeria who were non-smokers, the PEFR varied with type of cooking fuel used; the lowest values were associated with the use of biomass fuels. Furthermore, over one-fifth of study participants had

<table>
<thead>
<tr>
<th>Table 1. Comparison of study participants by fuel use category.</th>
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<tbody>
<tr>
<td>Participants characteristic</td>
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<tr>
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</tr>
<tr>
<td>Sample size</td>
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<tr>
<td>Age, mean years, SD</td>
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<tr>
<td>Educational level, n (%)</td>
</tr>
<tr>
<td>None</td>
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<tr>
<td>Primary</td>
</tr>
<tr>
<td>Secondary</td>
</tr>
<tr>
<td>Tertiary</td>
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<tr>
<td>Occupation, n (%)</td>
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<tr>
<td>Farming</td>
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<tr>
<td>Trading</td>
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<tr>
<td>Student/unemployed</td>
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<tr>
<td>Skilled worker</td>
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<tr>
<td>Time spent cooking/day, mean minutes (SD)</td>
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<tr>
<td>Poorly ventilated kitchen, n (%)</td>
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<tr>
<td>Family history of respiratory disease, n (%)</td>
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<tr>
<td>Weight (kg), mean (SD)</td>
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<td>Height (cm), mean (SD)</td>
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<tr>
<td>BMI (kg/m²), mean (SD)</td>
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<tr>
<td>Systolic BP, mean (SD)</td>
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<td>Diastolic BP, mean (SD)</td>
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</tbody>
</table>

Unless otherwise stated, the values are expressed as mean (SD) with significant ANOVA values at P<0.05. Categorical variables are compared using the chi-square test. *P<0.05 following LSD post hoc analysis. BMI, body mass index; SD, standard deviation.

<table>
<thead>
<tr>
<th>Table 2. Comparison of study participants by fuel use category.</th>
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<tbody>
<tr>
<td>Variable</td>
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<tr>
<td>Peak expiratory flow rate, mean (SD)</td>
</tr>
<tr>
<td>Abnormal peak expiratory flow rate, n (%)</td>
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</tbody>
</table>

Values are expressed as n (%) with significant chi-square values at P<0.05.
abnormal PEFR while biomass fuel users had the highest prevalence of abnormal PEFR. The high prevalence observed among biomass fuel users may be related to the fact that when cooking with firewood, women tend to sit near the fires for long periods compared to when cooking with kerosene or LPG.

The findings from this study are consistent with studies among rural women in other parts of the world. In a community-based cross-sectional study of 760 non-smoking women in India, abnormal PEFR was seen in almost one-third of the study population, with the highest prevalence among women using biofuels compared to those using kerosene, and those using LPG and mixed fuels. Similar to our findings, fuel type was a significant independent predictor of abnormal PEFR in their study. In another study conducted among women in an urban slum in South India, Dutt et al. found that women who used biomass as fuel had higher prevalence of respiratory symptoms and reduced pulmonary function compared with women who used kerosene or LPG.

Furthermore, our findings are similar to those of other researchers in sub-Saharan Africa. The prevalence of respiratory symptoms and reduced lung function among women exposed to indoor air pollution from biomass fuel burning was assessed in a Cameroonian study. The investigators found that women who used wood had symptoms suggestive of chronic bronchitis and there was a significant association between reduced lung function (which they assessed via FEV1) and type of cooking fuel. Dienye et al. in southern Nigeria carried out a cross-sectional study of 210 women, and found that women involved in exposure to smoke from biomass fuels as an occupational hazard had a higher prevalence of respiratory symptoms and had lower PEFR values when compared to controls. In a rural community in Ekiti state in Nigeria, a study of 269 women found that women who used biomass fuels were more likely to report respiratory symptoms and have lower FEVI, forced vital capacity (FVC), FEVI/FVC ratio, and PEFR. A cross-sectional study of 588 participants in Uganda identified biomass fuel used for home heating as a significant risk factor for COPD especially among former smokers.

Cigarette smoking is a recognized risk factor for airway diseases, especially COPD. In Africa, even with lower rates of smoking, COPD is still a major cause of morbidity and mortality and existing literature supports the link between biomass smoke exposure and COPD. A meta-analysis of 25 studies showed that women exposed to biomass fuels compared to kerosene or LPG, had 2.4-fold and 1.5-fold increases in the risk of developing COPD and chronic bronchitis, respectively. Similarly, another meta-analysis of 19 cross-sectional and five case–control studies showed that indoor biomass fuel smoke exposure compared to other fuels, independently increased the risk of COPD among women with an odds ratio of 1.38.

The adverse effect of chronic smoke exposure on pulmonary function is postulated to be due to the inflammatory effect of the constituents of biomass smoke on the airway. Biomass fuel exposure is a modifiable risk factor for COPD, and some studies have shown improvements in airway function when cleaner fuels are used or more efficient cookstoves are used to burn these fuels so that they release less respirable pollutants into the atmosphere. The implications of these findings are that these hazards need to be mitigated by concerted efforts to provide alternative cleaner fuels or at the very least improved cook stoves that are more efficient at burning solid fuels. In addition, there is a dire need for electrification of rural areas to reduce dependence on biomass fuels as well as strategies for poverty alleviation to help households move up the energy ladder. The association between biomass smoke exposure and reduced PEFR found in this study, needs to be confirmed with a larger study using more objective measures like spirometry testing. This will aid in guiding policies for the implementation of preventive strategies to protect vulnerable women from chronic obstructive airway disease.

Limitations
This was a cross-sectional study and thus the findings are hypothesis-generating and cannot prove causality. The peak flow measurements were taken at one time point and as such normal diurnal variability was not considered however, we tried to maintain uniformity by assessing the PEFR in the morning for all participants.

Conclusion
Biomass fuel combustion is known to adversely affect the respiratory system. This cross-sectional study contributes to the existing knowledge by demonstrating that exposure to biomass fuel among rural women in southern Nigeria was associated with lower PEFR compared to kerosene or LPG after adjusting for confounding variables. This suggests that the continued use of biomass fuel confers a real risk for obstructive airway disease for these women. It underscores the need for community education campaigns on the potential hazards of domestic biomass fuel use.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds ratio</th>
<th>95% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomass fuel</td>
<td>3.8</td>
<td>1.10, 12.83</td>
<td>0.034</td>
</tr>
<tr>
<td>Non-adjusted</td>
<td>5.8</td>
<td>1.62, 20.52</td>
<td>0.007</td>
</tr>
<tr>
<td>Adjusted</td>
<td>1.5</td>
<td>0.39, 5.76</td>
<td>0.557</td>
</tr>
<tr>
<td>Kerosene</td>
<td>1.7</td>
<td>0.43, 6.72</td>
<td>0.449</td>
</tr>
</tbody>
</table>
Data availability

Underlying data

PRF data file.xls contains complete raw data for this study.

Extended data

Biomass questionnaire.docx contains a copy of the questionnaire administered to each participant.

Data are available under the terms of the Creative Commons Zero “No rights reserved” data waiver (CC0 1.0 Public domain dedication).

Grant information
This research is supported by funding from the Department for International Development (DFID) under the Climate Impact Research Capacity and Leadership Enhancement (CIRCLE) programme.

References


3. Ambient (outdoor) air quality and health. Reference Source


31. Dutt D, Srinivasa DK, Rotti SB, et al.: Effect of indoor air pollution on the


Open Peer Review

Current Peer Review Status: ✔️ ❓

Version 1

Reviewer Report 15 August 2019

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Ajay Pillarisetti
Environmental Health Sciences, School of Public Health, University of California, Berkeley, Berkeley, CA, USA

This is a thorough, useful, and fairly well-written piece. Nice work. I have a number of suggestions and questions; if addressed, the piece merits publication and adds to the scientific literature.

1. I suggest using the term "household air pollution" in place of "indoor air pollution" throughout -- standard in the field for the past decade or so. You do use it in the paper, but not consistently.

2. What is a brief medical history?

3. Replace 'biomass' with 'solid fuels'.

4. I would rephrase the sentence in the introduction regarding where air pollution occurs in majority. In households using solid fuels, it is true that the majority of exposure occurs in indoors. In non-solid fuel using households, this may not be true.

5. Is there any more recent evidence on solid fuel use in Nigeria? Perhaps modelled estimates from the State of Global Air (available on the web) or WHO?

6. Clarify the sampling: did you have a list of all available households in each community and village? Or?

7. How was poor kitchen ventilation assessed?

8. Did you track potential occupational exposures to smoke?

9. How was LPG procured?

10. Did households with LPG or Kerosene use biomass/solid fuels at all? This phenomenon of stacking is common in household energy studies. Please add as a limitation if not assessed.
11. Was an asset index or other metric of wealth calculated? If so, did you include it in your models?

12. I strongly suggest that you discuss your BP findings. They are as interesting as the PEFR findings.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Household Air Pollution, Air Pollution Health Effects, Burden of Disease, Exposure Assessment

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 15 April 2019
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Gregory E. Erhabor
Obafemi Awolowo University (OAU), Ile-Ife, Osun, Nigeria

General comment:

The article is well written and contributes to the increasing science of adverse effect of biomass smoke; however the authors need to address some specific issues.
**Specific comments:**

**Abstract:**

**Methods:**
- What is meant by a brief medical history?
- Coal is not a biomass; it is a solid and fossil fuel. Do the authors mean coal or charcoal?

**Results:**
- The PEFR of women who use LPG...this is a repetition of the result in the second sentence, so it is not necessary.

**Conclusion:**
- COPD may not be the only respiratory disease that is associated with biomass fuel use and reduction in PEFR does not only mean obstructive airway disease.

**Introduction:**
- The introduction appears to be too long and redundant; this section can be shortened so as to make it more focused on the subject matter.

**Methods:**

**Study design:**
- What exactly is the larger study? More information is needed on what the larger study is.

**Study population and procedures:**
- "A brief medical history"...which questionnaire was used and what was the content of the brief medical history?
- The predicted equation used in this study should be referenced and is it corrected for race if it is not a Nigerian or African derived one?

**Results:**
- Are these fuels used the predominant type or the combination of fuels used amongst the women? For instance, it is possible for a woman to use kerosene and biomass and also use kerosene and LPG?
- The data on PEFR would have been more reliable if comparisons based on different fuel users were based on predicted PEFR because the biomass fuel users were significantly older and shorter; this could account for the lower PEFR seen in them.

- Table 3:
  1. Does the author mean family history for respiratory symptoms or history for respiratory symptoms?
  2. History for respiratory symptoms was an exclusion criteria.
  3. After adjustment, the odd ratio increases, this may suggest some interactions between the factors: these things should be explained.

**Discussion:**
- The authors need to elaborate more on the implication of their study and also to discuss limitations specific to their study like the use of PEFR.

**Is the work clearly and accurately presented and does it cite the current literature?**
- Yes
Is the study design appropriate and is the work technically sound?  
Yes

Are sufficient details of methods and analysis provided to allow replication by others?  
Yes

If applicable, is the statistical analysis and its interpretation appropriate?  
Yes

Are all the source data underlying the results available to ensure full reproducibility?  
Yes

Are the conclusions drawn adequately supported by the results?  
Yes

**Competing Interests:** No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.