Association of Low Birthweight and Indoor Air Pollution: Biomass Fuel Use in Bangladesh

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Introduction

There is growing evidence highlighting the acute and chronic adverse effects of air pollution in general and indoor air pollution on human health in particular. Air pollution has become a serious concern for developing countries in terms of intensity of exposure, total exposure time, and number of people exposed.¹ Approximately 76% of particulate matter air pollution around the world occurs indoors in developing countries.¹ Presently, there is considerable recognition that indoor use of biomass fuels is primarily responsible for some of the highest levels of air pollution and is a dominant factor contributing to the national burden of disease.² ³

Background. More than 90% of all low birthweight (LBW) babies are born in developing countries, and half of the population in developing nations uses solid fuels as their primary source of energy for cooking. An association between household use of solid biomass fuels and reduced newborn weight has been found in a number of countries. Bangladesh has a high prevalence of LBW babies (22%), and 88% of the population use solid fuels for cooking. Objectives. This study aims to explore whether indoor air pollution is associated with LBW in Bangladesh, an important determinant of infant mortality and morbidity.

Methods. The 2011 Bangladesh Demographic and Health Survey (BDHS) was used for the present analysis. The total number of births reported in the previous five years by respondents in the survey sample was 8,753. Mothers’ recall of their baby’s weight was the dependent dichotomous variable. A mixed effects logistic regression model was fitted using region as a random effect and several independent fixed effects.

Results. High pollutant cooking fuels, such as coal and wood, resulted in higher odds of having a LBW child compared to use of electricity/gas (odds ratio (OR): 2.6, confidence interval (CI): 1.1-6.2 and OR: 1.1, CI: 1.0-1.2). Factors which lowered the odds include mothers with a bachelor’s degree or higher education (OR: 0.6, CI: 0.4-0.9), third order children (OR: 0.8, CI: 0.6-0.9), fourth or higher order children (OR: 0.8, CI: 0.6-1.0), having a male child (OR: 0.7, CI: 0.7-0.8), and receiving sufficient antenatal care (OR: 0.8, CI: 0.6-0.9). Factors which increase the odds of having a LBW infant include mothers who are underweight compared to normal weight mothers (OR: 1.1, CI: 1.1-1.2), mistimed pregnancies (OR: 1.2, CI: 1.0-1.4), or unplanned pregnancies (OR: 1.3, CI: 1.0-1.7), compared to planned pregnancies.

Conclusions. This is the first paper to show an association between use of highly pollutant biomass fuel and prevalence of LBW babies in Bangladesh, suggesting that besides polluting the air and causing respiratory illnesses, biomass fuel combustion may also affect the health of fetuses in utero. Further longitudinal studies are required to establish this finding among mothers in developing countries.

Ethics Approval. This study was exempted from ethical review approval by the University of South Carolina Institutional Review Board (USC IRB), because it uses publicly available, de-identified data.

Competing Interests. The authors declare no competing financial interests.

Keywords. child health, low birthweight, biomass fuel, air pollution and health, global health, Bangladesh
disease burden is largely borne by women in rural communities who are the primary cooks in households.\(^4\)\(^7\) It is essential to examine the effect of polluted indoor air exposure and its adverse effects on human health in developing countries.

Solid fuels including wood, agricultural crops, animal dung, straw, shrubs, grass, and charcoal are the primary source of cooking material for around half of the population in developing countries.\(^8\) Smoke from burning solid fuels produces significant amounts of life threatening air pollutants including particulate matter, formaldehyde, carbon monoxide, nitrogen oxides, benzene, hydrocarbons, and many other toxic organic compounds.\(^9\)\(^10\) In developing countries, where a large proportion of households rely on solid fuels for cooking, heating and lighting, concentrations of these air pollutants indoors tend to be high. Traditional cooking stoves are typically simple, inefficient at combusting solid fuel and used mostly in unventilated households which produces large volumes of indoor smoke. As a result, daily peak and average exposures to hazardous air pollutants often far exceed the safe levels (recommended 24-hour mean: PM2.5 < 25 \(\mu g/m^3\) and PM10 <50 \(\mu g/m^3\)) recommended by the World Health Organization (WHO).\(^11\) In homes where solid fuels are used for cooking, levels of carbon monoxide are sometimes considered high enough to result in toxic carboxyhemoglobin levels.\(^12\)

In many settings, the association between air pollution and respiratory disease is evident, but little is known about its effects on pregnancy outcomes, such as low birthweight (LBW). LBW, defined as birthweight less than 2,500 grams, is a significant risk factor of post-neonatal mortality and morbidity in both developed and developing countries.\(^6\)\(^13\) More than 90% of all LBW babies are born in developing countries.\(^14\) One of the first studies reporting a relationship between household use of solid fuels and reduced birthweight was performed in rural Guatemala.\(^14\) Babies were found to have 63 grams lower birthweight on average for mothers who used solid fuels for cooking compared to mothers using gas or electricity. Some studies have found an association between maternal exposure to indoor air pollution from burning solid fuels and adverse pregnancy outcomes, including intrauterine growth retardation (IUGR), preeclampsia/eclampsia and LBW.\(^11\)\(^15\)\(^17\)

In Bangladesh, 88% of the population uses solid fuels for cooking and between 2005-2006, 22% of all births fell into the category of LBW.\(^18\)\(^19\) The purpose of the present study was to explore whether air pollution is associated with LBW, an important determinant of infant mortality and morbidity. To investigate this relationship, we examined maternal exposure to indoor air pollution using data from the Bangladesh Demographic and Health Survey (BDHS) 2011, which collected demographic, socioeconomic, and health information from 18,000 ever-married women aged between 15-49 years.

The nationally representative survey collected data on demographic, socioeconomic, and health information of household members, including mothers and children. In the BDHS 2011 survey, the total number of births reported in the previous five years was 8,753. More details about the survey can be found elsewhere.\(^20\) This study was exempted from ethical review approval by the University of South Carolina Institutional Review Board (USC IRB), because it uses publicly available, de-identified data.

### Methods

#### Data Source

This study uses birth data from the 2011 BDHS. The BDHS is a nationally representative survey conducted periodically. It follows a multi-stage stratified cluster sampling method. The 2011 survey randomly selected 600 clusters, 393 from rural and 207 from urban strata. These clusters were originally demarcated for decennial census by the Bangladesh Bureau of Statistics and served as the primary sampling units (PSU) for the BDHS. The survey randomly took 30 households from each PSU, resulting in a total of 18,072 interviews of ever-married women aged between 15-49 years.
what was the size of the baby?” The options were ‘very large’, ‘larger than average’, ‘average’, ‘smaller than average’, and ‘very small’. An infant was classified as being LBW if the mother reported that they were ‘very small’ or ‘smaller than average’. A previous study which used this subjective evaluation of birthweight compared it to actual birthweight and found that the results were quite consistent. This is useful for countries such as Bangladesh where the majority of births take place at home and newborn birthweight is not generally measured.

**Independent Variables**

In the present study, the main independent variable of interest was cooking fuel type and kitchen location. Fuel types were categorized into four groups: electricity/gas (including electricity, liquefied petroleum gas (LPG), natural gas, biogas, and kerosene), coal (including coal, lignite, and charcoal), wood, and straw/crop (including straw/shrubs/grass, agricultural crop, and animal dung). Location of kitchen was dichotomized as indoor or outdoor. The interaction between type of fuel and location of kitchen was also assessed. Other independent variables included in the model were maternal age in years (15-19, 20-29, 30-49 years), maternal education (none, primary, secondary, bachelor’s degree or higher), maternal body mass index (BMI) (normal, underweight, overweight or obese), wealth index (1 to 5 from poorest to richest), calculated based on availability of household assets, adjusting for urban-rural differences as a control since other studies have reported in all BDHS data, which is constructed using principal components analysis on the possession of different household assets, adjusting for urban-rural differences. Antenatal care was classified based on World Health Organization recommendations as sufficient if pregnant women made at least four or more visits during pregnancy and insufficient if they made three visits or less. Almost three-quarters (77%) of the mothers who received sufficient antenatal care received it from a medically trained provider. Pregnancy intention was categorized into three groups based on whether the birth or pregnancy was wanted then (planned), wanted later (mistimed), or unwanted (unplanned) at the time of conception.

**Data Analysis**

To gain a better understanding of the data, descriptive statistics of all relevant variables were reported. To determine crude associations between each of the independent variables and LBW, crude odds ratios (OR) and corresponding 95% confidence intervals (CI) were calculated and reported. To assess the relationship between cooking fuel and birthweight, we ran a mixed effects logistic regression model where the log odds of LBW were modeled as a linear combination of several fixed independent variables and region treated as a random independent variable. Adjusted OR along with their corresponding 95% CI were reported. Although the interaction between type of fuel and kitchen location was not significant, it was kept in the model as a control since other studies have highlighted the interrelationship between these two variables. In addition, a likelihood ratio test of the model with and without the interaction term did not show any significant difference. Region was incorporated as a random effect since there were substantial variations in birthweight across regions. To verify that region was most appropriately modelled as a random effect rather than a fixed effect, a likelihood ratio test was conducted. This resulted in a chi-square test statistic of 18.42 and corresponding p-value of 0.0025, which allowed us to conclude that region as a random effect was significantly better at predicting the odds of low birthweight than as a fixed effect. All statistical analyses were performed using STATA 14.0.

**Results**

Our study included a total of 8,753 births in the five years prior to 2011, half (48.6%) of which were female (Table 1). About 17.6% of newborns were reported to have low birthweight. More than one third (36.7%) of these births were first in order and almost 30% were second in order. Most (63.5%) of the mothers were between 20-29 years of age, with normal BMI (60.0%), and residing in rural areas (69.5%). The highest education attained by most (42.2%) of the mothers was secondary education. Most (73.6%) of the mothers received insufficient antenatal care, even though most of the pregnancies were planned (73.2%). In total, 88% of mothers were exposed to high pollutant cooking fuels such as coal, wood, and straw/crops. Almost one-fifth (17.6%) of the mothers cooked in kitchens inside the household.

Results of the bivariate analyses are shown in Table 2. These crude results show that wood and straw/crop cooking fuels result in higher odds of having a LBW child compared to electricity/gas (OR: 1.3, CI: 1.1-1.6 and OR: 1.4, CI: 1.1-1.7). A mother having secondary (OR: 0.8, CI: 0.7-0.9) or higher education (OR: 0.5, CI: 0.4-0.7),
Association of Low Birthweight and Indoor Air Pollution: Biomass Fuel Use in Bangladesh

Characteristics

| Variables          | n (%)        |
|--------------------|--------------|
| Birthweight        |              |
| Low Birthweight (LBW) | 1543 (17.6) |
| Normal             | 7205 (82.4) |
| Fuel               |              |
| Electricity/Gas    | 942 (12.0)  |
| Coal               | 32 (0.4)    |
| Wood               | 4050 (51.6) |
| Straw/Crop         | 2826 (36.0) |
| Location of Kitchen|              |
| Indoor             | 1537 (17.6) |
| Outdoor            | 7207 (82.4) |
| Maternal Age       |              |
| 15 – 19            | 1167 (13.4) |
| 20 – 29            | 5547 (63.5) |
| 30 – 49            | 2028 (23.2) |
| Maternal Education |              |
| None               | 1687 (19.3) |
| Primary            | 2684 (30.7) |
| Secondary          | 3690 (42.2) |
| Bachelor’s Degree or Higher | 692 (7.9) |
| Maternal BMI       |              |
| Normal             | 5135 (60.0) |
| Underweight        | 2357 (27.5) |
| Overweight or Obese| 1065 (12.5) |
| Wealth Index       |              |
| 1                  | 1935 (22.1) |
| 2                  | 1711 (19.6) |
| 3                  | 1661 (19.0) |
| 4                  | 1722 (19.7) |
| 5                  | 1724 (19.7) |
| Birth Order        |              |
| First              | 3122 (36.7) |
| Second             | 2532 (28.9) |
| Third              | 1495 (17.1) |
| Fourth or Higher   | 1604 (18.3) |
| Sex of Child       |              |
| Female             | 4251 (48.6) |
| Male               | 4502 (51.4) |
| Antenatal Care     |              |
| Insufficient       | 5385 (73.6) |
| Sufficient         | 1933 (26.4) |
| Pregnancy Intention|             |
| Planned            | 6402 (73.2) |
| Mistimed           | 1277 (14.6) |
| Unplanned          | 1071 (12.2) |
| Residence          |              |
| Urban              | 2674 (30.6) |
| Rural              | 6079 (69.5) |
| Region             |              |
| Barisal            | 977 (11.2)  |
| Chittagong         | 1750 (20.0) |
| Dhaka              | 1445 (16.5) |
| Khulna             | 982 (11.2)  |
| Rajshahi           | 1083 (12.4) |
| Rangpur            | 1107 (12.7) |
| Sylhet             | 1409 (16.1) |

Table 1 — Sociodemographic Characteristics of Mothers in the Bangladesh Demographic and Health Survey 2011, BDHS 2011 (N=8753)

Discussion

This study reveals an association between risk of LBW and indoor air pollution from high pollutant biomass fuel combustion affecting pregnant...
women in Bangladesh. A similar association has been found in several other studies conducted in developing countries such as Guatemala, India, Pakistan, China, and Zimbabwe. 

Pregnant women in Bangladesh, like other developing countries, are not exempted from cooking regularly and are exposed to highly pollutant carbon dioxide (CO$_2$) and carbon monoxide (CO) laden air for a prolonged period of time. This is a concern as polluted air may hamper the required transplacental oxygen supply to the fetus and can cause intrauterine growth retardation (IUGR) of varying degrees and types.

Besides highly pollutant biomass fuels, several other maternal and child factors have an effect on the risk of having a LBW child. Mothers who were educated and had a male child were found to have less risk of having a LBW baby. Higher birth order was protective of low birthweight in our study, which is consistent with the findings in several studies. Factors associated with a higher risk of having LBW babies include the mother being underweight, having insufficient number of antenatal care visits during pregnancy, and having a mistimed or unplanned pregnancy. These findings are similar to several studies performed in developing and developed countries.

Most residents of the rural areas of Bangladesh use biomass fuel for cooking purposes, while the prevalence is lower in urban areas. One of the reasons for this is because the high pollutant biomass fuels are more readily available and less expensive in rural areas than other types of cooking fuels. However, biomass fuel consumption in urban areas is on the rise because of the burgeoning slum areas in the cities where impoverished people rely on cheap biomass fuels for household cooking.

| Characteristics | Bivariate | Mixed Logit Model |
|-----------------|-----------|-------------------|
| **Fuel**        |           |                   |
| Electricity/Gas | 1.0       | 1.0               |
| Coal            | 1.4       | 2.6*              |
| Wood            | 1.3**     | 1.1*              |
| Straw/Crop      | 1.4**     | 1.1               |
| **Location of Kitchen** | 1.0       | 1.0               |
| Indoor          | 0.9       | 0.9               |
| Outdoor         | 0.8 – 1.1 | 0.7 – 1.2         |
| **Fuel*Kitchen Location** | 1.0       | 1.0               |
| Electricity/Gas*Indoor | 0.3       | 0.2               |
| Coal*Indoor     | 1.4       | 0.9 – 1.2         |
| Wood*Indoor     | 1.4       | 0.9 – 1.4         |
| Straw/Crop*Indoor | 1.4       | 0.9 – 1.4         |
| **Maternal Age** |           |                   |
| 20 – 29         | 1.0       | 1.0               |
| 15 – 19         | 1.3**     | 1.1               |
| 30 – 49         | 1.1       | 1.0 – 1.3         |
| **Maternal Education** | 1.0       | 1.0               |
| None            | 0.9       | 0.9               |
| Primary         | 0.8 – 1.0 | 0.8 – 1.1         |
| Secondary       | 0.8***    | 0.9 – 1.2         |
| Bachelor or Higher | 0.5***    | 0.4 – 0.9         |
| **Maternal BMI** |           |                   |
| Normal          | 1.0       | 1.0               |
| Underweight     | 1.2*      | 1.1**             |
| Overweight or Obese | 0.8       | 0.9               |
| **Wealth Index** |           |                   |
| 1               | 1.0       | 1.0               |
| 2               | 0.9       | 0.9 – 1.1         |
| 3               | 0.9       | 0.9 – 1.0         |
| 4               | 0.8**     | 0.8               |
| 5               | 0.7***    | 0.6 – 1.3         |
| **Birth Order** |           |                   |
| First           | 1.0       | 1.0               |
| Second          | 0.8*      | 0.8               |
| Third           | 0.9       | 0.6 – 0.9         |
| Fourth or Higher | 1.1       | 0.6 – 1.0         |
| **Sex of Child** |           |                   |
| Female          | 1.0       | 1.0               |
| Male            | 0.8***    | 0.7 – 0.8         |
| **Ante-natal Care** | 1.0       | 1.0               |
| Insufficient    | 0.7***    | 0.6 – 0.8         |
| Sufficient      |           |                   |
| **Pregnancy Intention** | 1.0       | 1.0               |
| Planned         | 1.0       | 1.0               |
| Mistimed        | 1.1       | 1.2*              |
| Unplanned       | 1.2*      | 1.3               |
| **Residence**   |           |                   |
| Urban           | 1.0       | 1.0               |
| Rural           | 1.1       | 0.9               |

Table 2: Bivariate Analysis and Mixed Effects Logistic Regression for Low Birthweight Infants in Bangladesh, BDHS 2011 (N=8753)

a OR = Odds Ratio  
b 95% CI= 95% Confidence Interval.  
c AOR = Adjusted Odds Ratio  
*p<0.05; **p<0.01; ***p<0.001
The practice of burning biomass fuel reduces forest density all over the world. At the same time, mothers suffer from obstetric complications and newborn babies suffer from still births, developmental anomalies, and morbidity and mortality as a consequence of LBW.\(^3\) Altogether, the practice of biomass fuel combustion has long term implications on the environment, as well as on population health. The association of the risk of LBW and highly pollutant cooking fuel falls under the purview of several target areas of the Sustainable Development Goals (SDGs) chalked out by the United Nations (UN) to be implemented after expiration of the Millennium Development Goals (MDGs) in 2015, e.g., health and nutrition, forest and natural resources, desertification, energy use, climate change, etc. Clean cookstoves have been proffered as the solution to this important health and environmental problem. The Global Alliance for Clean Cookstoves, a UN Foundations initiative, aims to help 100 million households to adopt clean cookstoves by 2020. They have selected several focus countries to target, one of which is Bangladesh, but the initiative is still in the early stages, designing a workable business model for sustainable adoption of clean stoves.

A strength of the present study is the use of nationally representative data which allows us to make conclusions about the general population based on this sample. One limitation of this study is that self-reported birthweight is prone to recall bias and rounding-off errors, as well as misreporting. Unless a newborn suffers from significant health issues and complications, mothers tend to report normal birthweight. Therefore, the findings in this study may underestimate actual risk. Future research on this issue will benefit from actual birthweight data, either through weighing of babies within a few days of birth or from medical records, in cases of institutional delivery. Since a significant proportion of births take place at home in Bangladesh, birthweight information is relatively unreliable unless birth attendants collect the information. Another limitation of the study is defining the degree of indoor air pollution. We used type of cooking fuel and kitchen location in relation to household living quarters as indicators of indoor air quality. The data set does not include any direct measure of indoor air quality. Confidence in empirical results would be improved by measuring air quality directly. Pre-term birth is another important determinant of low birthweight which is missing in BDHS data and future research should also collect this information.

**Conclusions**

To our knowledge, this paper is the first to demonstrate that cooking with high pollutant biomass fuels such as coal and wood is associated with a higher odds of having LBW babies in Bangladesh (OR: 2.6, CI: 1.1-6.2 and OR: 1.1, CI: 1.0-1.2). This suggests that besides polluting the air and causing respiratory illnesses, biomass fuel combustion may also affect the health of the fetus in utero. However, this study does not provide a definitive causal link between indoor air pollution from biomass fuel and LBW. Further longitudinal studies are needed to establish this finding among mothers of developing countries.

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