Original Research

Maternal biomass smoke exposure and birth weight in Malawi: Analysis of data from the 2010 Malawi Demographic and Health Survey

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Abstract

Background

Use of biomass fuels has been shown to contribute to ill health and complications in pregnancy outcomes such as low birthweight, neonatal deaths and mortality in developing countries. However, there is insufficient evidence of this association in the Sub-Saharan Africa and the Malawian population. We, therefore, investigated effects of exposure to biomass fuels on reduced birth weight in the Malawian population.

Methods

We conducted a cross-sectional analysis using secondary data from the 2010 Malawi Demographic Health Survey with a total of 9124 respondents. Information on exposure to biomass fuels, birthweight, and size of child at birth as well as other relevant information on risk factors was obtained through a questionnaire. We used linear regression models for continuous birth weight outcome and logistic regression for the binary outcome. Models were systematically adjusted for relevant confounding factors.

Results

Use of high pollution fuels resulted in a 92 g (95% CI: -320.4; 136.4) reduction in mean birth weight compared to low pollution fuel use after adjustment for child, maternal as well as household characteristics. Full adjusted OR (95% CI) for risk of having size below average at birth was 1.29 (0.34; 4.48). Gender and birth order of child were the significant confounders factors in our adjusted models.

Conclusions

We observed reduced birth weight in children whose mothers used high pollution fuels suggesting a negative effect of maternal exposure to biomass fuels on birth weight of the child. However, this reduction was not statistically significant. More carefully designed studies need to be carried out to explore effects of biomass fuels on pregnancy outcomes and health outcomes in general.

Introduction

As of 2011, one-third of the world and 90% of the rural household population in developing countries was using biomass fuels as a source of energy for domestic use. Biomass fuels include wood, charcoal, animal dung, and crop residues. Fires from these contribute to household air pollution (HAP) by releasing noxious pollutants, e.g particulate matter (PM), carbon monoxide (CO), nitrogen dioxide (NO_2).[1] Globally HAP contributes to 40% of the burden of disease and causes 2 million deaths in developing countries.[1] HAP is also associated with increased risk for several acute and chronic health conditions, including acute respiratory infections (ARI), pneumonia, tuberculosis, chronic lung disease, cardiovascular disease, cataracts, and cancers.[2] In Malawi, HAP has been labelled as the fifth-largest risk factor for burden of disease.[3] Over 95% of households depend on biomass for fuel and household air pollution levels are high and well beyond WHO safe limits.[4] HAP has also been noted to increase the risk of pneumonia by 80% in the Malawi population, a leading cause of mortality among children younger than 5 years of age but also pre-dispose to conditions such as low birth weight, nutritional deficiencies, anemia, stunted growth and babies born small for gestational age.[3,4]

There has been significant and notable documentation connecting HAP to adverse health outcomes especially due to exposures inutero or in early life.[5–9] Low birth weight (< 2500g) has been suggested as an important result of exposure to household air pollution resulting from cooking fuels in developing countries.[7] Low birth weight is a precursor for adulthood health and in particular cardiovascular diseases as low birthweight children have been shown to have a higher risk of suffering from multiple health problems including cardiovascular diseases later in life.[10,11]

A study in Guatemala that investigated the association between maternal exposure to smoke and reduced birth weight indicated that children born in households using high pollution fuels were 73 g lighter than those born in households using low pollution fuels.[12] A similar study done in Zimbabwe showed that children whose mothers were exposed to biomass fuels were 175 g lighter than electricity and gas users.[13] Similarly, studies from Ecuador and Czech Republic have also shown that the effect on birth weight is dependent on the type of fuel used.[1] Tielsch et al.[14] noted that 92.3% of wood/dung use was associated with 49% increased low birth weight and 30% risk of stunting at 6 months in India. Overall the developed countries use more fuels than developing countries but developing countries have high population overall rates of household air pollution. The Cooking and Pneumonia Study (CAPS) an intervention on effects of biomass fuel use on child pneumonia rates[4] is the only study in Malawi that has explored effects of biomass fuels exposure on child health. There is no Malawian study that has explored the effects of exposure to biomass fuels on pregnancy outcomes specifically reduced birthweight. We aim to investigate the effect of exposure to biomass fuels on reduced birth weight in the Malawian population.

Methods

Study population and data

Demographic Health Surveys (DHS) are nationally representative surveys conducted approximately every 5 years in many low and lower-middle income countries using multistage stratified probabilistic sampling.[15]

The most recent available Malawian standard DHS data at the time of analysis was from the 2010 wave such that data was obtained from the 2010 standard DHS survey largely funded by USAID and conducted in conjunction with the National Statistical Office. The standard DHS collects data on multiple indicators of health and social and demographic characteristics as well data on reproductive life. The 2010 wave of data collection encompassed a total of 27,000 households and involving 24,000 female and 7,000 male respondents.[16]

The current study is a cross-sectional study and the sample comprises of all households that had children under five years of age and had complete data on both birthweight / size at birth and main type of cooking fuel. Multiple births, (twins)children whose households responded "other" or "no food cooked in the household" to the type of cooking fuel used were excluded from analysis e.g cases in rural areas where multiple households in a compound eat food cooked from one household. The final sample size was 9124 (Figure S1).

Statistical analysis

Outcome variable

Birth weight measured at birth and size at birth were the outcome variables used in this analysis. During the interview, mothers were asked if their child was weighed at birth and if they had a health card showing child's birthweight from where it was recorded. If not, mothers were asked if they recall the size of their child at birth. In addition, mothers were also asked to classify the size of their child at birth on a 5-category scale; very large, large, average, below average and small. This variable was used to create a binary variable for size at birth, 0 for above average and 1 for below average. Measured/recalled birth weight was used as a continuous variable in the analysis and size at birth (average and above/ below average) was modelled as a binary response variable. Both variables have been used in the analysis.

Exposure assessment

Maternal exposure to biomass fuels was determined through the household questionnaire. During the interview, mothers were also asked what type of cooking fuel they mainly use for cooking. Respondents could choose among electricity, liquefied petroleum gas (LPG), biogas, kerosene, charcoal, wood, crops or straw and dung. The types of fuels were categorized into low and high pollution fuels. Electricity, LPG and biogas were regarded as low pollution fuels and charcoal, wood, crops, straw and dung were regarded as high pollution fuels.

Linear regression models were used to estimate the association between continuous birth weight and exposure to biomass fuels. Logistic models were used to examine the association with size at birth. Both models were controlled systematically for a set of potential child, maternal, and household confounding factors. Model 1 was the unadjusted crude model, model 2 was adjusted for child confounding factors i.e. birth order (birth number of child), gender of child(male/female). Model 3 was additionally adjusted for maternal factors i.e. maternal age (at birth), maternal BMI, maternal education (low/medium/ higher), maternal religion (Christian/non-Christian) and model 4, the full model, was model 3 additionally adjusted for household characteristics such as the Wealth Index (a composite measure of a household's cumulative living standard), place of residence (urban/rural). Tobacco smoking is normally considered as a confounder in the analysis of biomass fuel exposure and reduced birth weight but was not adjusted for in this analysis because frequencies were too low for smoking mothers (0.29 %).

As part of a sensitivity analysis, we stratified the analysis by whether birth weight was recalled by the mother or recorded from the health questionnaire. Since the size of the birth was already technically by recall we used the measured birth weight outcome variable for this part of the analysis. To investigate a direct comparison between wood and electricity/gas use we repeated part of the analysis by excluding charcoal users as it sometimes regarded as a 'medium or cleaner' fuel than wood. All analyses were conducted in SAS 9.4 (California USA) within the PROC SURVEY environment to take into account the survey nature of the data with significance level set at 0.05.

Table 1: Study characteristics based on cooking fuel type

Characteristics	High-pollution fuel (N = 9021) % (95 % CI)	Low-pollution fuel (N = 103) % (95 % CI)
Child gender		
Male	50.1	52.9
Female	49.9	47.1
Birth order		
1	19.9	37.9
2	19.7	35.6
3	17.2	14.3
4+	41.4	12.1
Size at birth		
Below average	12.5	8.7
Average+	87.4	91.2
Low birthweight(< 2500g)	10.1	13.5
Maternal education		
None	13.2	1.6
Primary	66.7	12.2
Secondary	19.2	46.7
Higher	0.7	39.9
Maternal religion		
Christian	86.1	92.1
Non-Christian	14.0	7.8
Wealth Index		
1st quintile	18.1	-
2nd quintile	19.6	-
3rd quintile	20.9	-
4th quintile	20.5	0.53
5th quintile	20.8	99.5
Residence		
Urban	17.4	90.8
Rural	82.5	9.1
	Mean (standard error)	Mean (standard error)
Maternal age (years)	18.4 (0.1)	22.1 (0.4)
Maternal BMI (kg/m^2)	24.4 (0.2)	26.2 (1.4)
Birthweight (g)	3260.3 (72.3)	3286.9 (10.7)

BMI = body mass index

Results

Table 1 shows the characteristics of the study population. More than 80% of the population were high pollution fuel users and only 1.6 % used electricity or gas for cooking consistent with the 2010 DHS final report.[16] High pollution population had the majority of uneducated mothers, whilst mothers in the low pollution group were fairly distributed across the different levels of education with at least 40% having attained a high level of education. Notably, the wealth quintiles are unequally distributed between the populations with most of the low pollution fuels users in the 5th wealth quintile which is the lower income quintile, as compared to only 20.8% of the high pollution group in this quantile. This is expected as most people who are exposed to high pollution fuels are low-income households and therefore reside in rural areas 82.5%. A comparison of the included and the excluded population (Table S1) showed that population characteristics were comparable also in terms of exposure except the excluded had most non-Christian respondents and there were more children with low birth weight in the excluded population than in our study population. The correlation between low birth weight and size at birth was 0.42 suggesting that 42% of the children had agreeing classification of below average (when using size of child at birth) and low birth weight (using recorded/recalled birth weight).

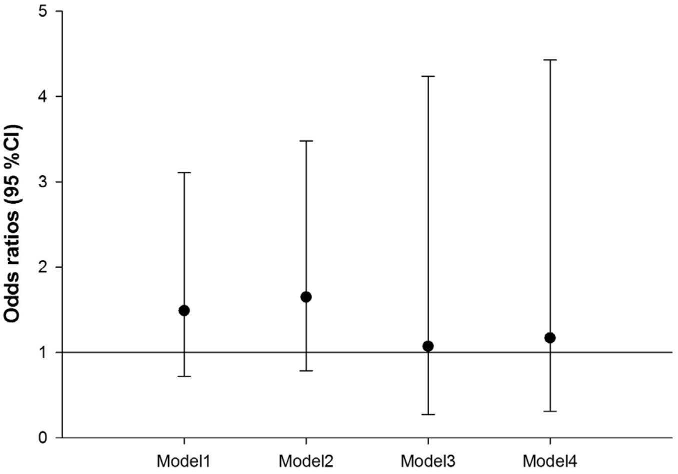

Figure 1: Odds ratios of the association between main cooking fuel type and size at birth for different models

Model 1 = crude model; Model 2 = Model 1 with adjustment for child characteristics (gender and birth order); Model 3 = Model 2 with additional adjustment for maternal characteristics (maternal age at delivery, maternal education, maternal body mass index [BMI], maternal religion); Full model = Model 3 with additional adjustment for wealth index and place of residence

*Estimates are in reference to low pollution, male child, 4th+ birth order, high maternal education, non-Christians, highest quintile wealth index, and urban residence

We consistently observed an elevated risk of reduced size at birth for the high pollution fuels as compared to low pollution fuels (Figure 1). However, none of the odds ratios were statistically significant. The risk seemed to be attenuated by adjustment for various confounders including child, maternal and household characteristics in the full model OR (95% CI) =1.29 (0.34; 4.80).

Table 2 shows regression estimates of reduction in mean birth weight obtained in all four models. A reduction in birth weight for children whose mothers use high pollution fuels as the main cooking fuel as compared to low pollution fuels is already observed in the crude models. In adjustment for

Table 2: Association of maternal use of biomass fuels with birthweight (grams), systematically adjusted for confounders

Predictor	Model 1	Model 2	Model 3	Full model
	Estimate (95% CI)	Estimate (95% CI)	Estimate (95% CI)	Estimate (95% CI)
High-pollution cooking fuel	–26.6 (–169.7 to 116.4)	–37.5 (–183.7 to 108.7)	–62.1 (–290.3 to 166.1)	–92.1 (–320.4 to 136.4)
Female child		–100.1 (–142.1 to -58.1)	–83.3 (–151.9 to -14.5)	–83.1 (–151.2 to –14.9)
Birth order				
1		–264.5 (–318.9 to –210.2)	–236.8 (–321.1 to –147.4)	–234.7 (–324.2 to -145.2)
2		–105.8 (–163.4 to –48.1)	–55.5 (–151.6 to 39.4)	–53.4 (–149.6 to 42.6)
3		–61.2 (–122.8 to 0.4)	14.7 (–95.6 to 125.3)	18.1 (–90.3 to 126.1)
Maternal age (years)			–9.8 (–22.8 to 3.05)	–9.5 (–22.6 to 3.63)
Maternal education				
Low			–260.9 (–556.6 to 34.6)	–262.1 (–536.8 to 39.7)
Medium			35.5 (–43.9 to 114.7)	37.1 (–46.7 to 120.7)
Maternal BMI (kg/m²)			–2.8 (–5.71 to 0.09)	–2.77 (–5.65 to 0.11)
Maternal religion			–95.1 (–191.9 to 1.7)	–89.9 (–186.4 to 6.49)
Wealth index				
Quintile 1				–32.7 to (–161.5 to 96.1)
Quintile 2				–24.2 to (–152.1 to 103.4)
Quintile 3				0.81 to (–104.7 to 106.4)
Quintile 4				38.1 to (–85.53 to 161.6)
Place of residence				
Rural				–47.2 (–167.4 to 72.9)

Model 1 = crude model; Model 2 = Model 1 with adjustment for child characteristics (gender and birth order); Model 3 = Model 2 with additional adjustment for maternal characteristics (maternal age at delivery, maternal education, maternal body mass index [BMI], maternal religion); Full model = Model 3 with additional adjustment for wealth index and place of residence

*Estimates are in reference to low pollution, male child, 4th+ birth order, high maternal education, non-Christians, highest quintile wealth index, and urban residence

Table 3: Sensitivity analysis, stratification by health card or recall, and exclusion of charcoal users*

Predictor	Health card Estimate (95% CI)	Recall Estimate(95% CI)	Charcoal users excluded Estimate(95% CI)
High pollution	–265.2 (–547.1 to 16.7)	–42.7 (–326.2 to 411.4)	–324.1 (–470.5 to –177.5)
Female child	–83.1 (–151.2 to –14.8)	–111.1 (–203.1 to –18.9)	–355.1 (–455.8 to –245.2)
Birth order			
1	–223.4 (–347.3 to –99.7)	–240.7 (–363.1 to 118.2)	–350.5 (–455.8 to –245.2)
2	–91.2 (–220.1 to 37.6)	–25.4 (–160.2 to 109.4)	–78.4 (–213.2 to 56.3)
3	–49.1 (–177.9 to 79.8)	72.1 (–80.3 to 224.6)	–64.6 (–18.7 to 58.3)
Maternal age (years)	–14.4 (–29.9 to 1.1)	–7.7 (–26.5 to 11.1)	–17.7 (–34.1 to –1.3)
Maternal education			
Low	–18.9 (–463.3 to 425.5)	–373.7 (–698.8 to –48.5)	–21.3 (–267.6 to 224.9)
Medium	116.5 (3.9 to 229.1)	3.9 (–104.9 to 112.7)	170.7 (76.7 to 264.7)
Maternal BMI (kg/m^2)	–1.23 (–5.2 to 2.8)	–3.7 (–7.5 to 0.3)	–3.88 (–7.2 to –0.57)
Maternal religion	–80.1 (–125.6 to 124.1)	–128.8 (–279.9 to 22.3)	–82.3 (–225.4 to 60.8)
Wealth Index			
Quintile 1	–25.6 (–146.1 to 197.4)	–72.7 (–251.6 to 106.1)	–9.6 (–152.5 to 133.3)
Quintile 2	–47.7 (–194.6 to 99.2)	–12.6 (–201.6 to 173.4)	–16.2 (–145. 5 to 112.9)
Quintile 3	-39.5 (-171.6; 92.6)	13.8 (–140.7 to 168.4)	–10.1 (–117.8 to 97.8)
Quintile 4	15.3 (-120.5 ; 151.2)	49.5 (–129.1 to 228.3)	23.8 (–72.1 to 119.8)
Place of residence			
Rural	–77.1 (–192.4 to 38.1)	–41.3 (–216.9 to 134.2)	–72.8 (–204.1 to 58.4)

*Model adjusted for gender and birth order, maternal age at delivery, maternal education, maternal body mass index (BMI), maternal religion, wealth index, place of residence. Estimates are in reference to low pollution, male children, 4th+ birth order, high maternal education, non-Christian religion, the highest quintile of wealth index, and urban residence for categorical predictors

child characteristics, girls were estimated to weigh at least 100 g less than their male counterparts and first borns had the most reduced weight at birth. Both these factors were significant in Model 2. Further adjustment by including both child and maternal characteristics also showed a reduction in the mean birth weight, with high-pollution fuels users giving birth to children that weigh at least 62 grams less than low pollution fuel users. The full model with full adjustment for available confounders also showed a reduction of 92 g (95% CI: -320.4; 136.4) in birth weight for children whose mothers were exposed to high pollution fuels,. The negative association of high pollution fuels with reduced birthweight was however not statistically significant in our analysis. The gender of the child and the birth order remained significant factors in all models.

When we stratified the analysis by measured birth weight and recalled birth weight, we observed a 265 g reduction in health card recorded birthweight and 111 g for recalled measurements (Table 3). Exclusion of charcoal users showed a significant reduction in mean birth weight for wood/dung users by 324g 95% CI (-470.6 -177.5) and maternal age at birth as well as birth order remained significant in this model.

Discussion

We investigated the effect of maternal exposure to biomass fuels through cooking and reduction of birth weight in children in the Malawian population. We observed a negative association between exposure to biomass fuels and reduced birthweight albeit non-significant.

The use of biomass fuels has rampantly increased in Malawi owing to economic challenges and the reduction in electrical power supply. There is limited documented evidence of effects of the use of biomass fuels on health in the Malawian population. Considering how the use of these fuels has increased over time, it is of vital public health concern that the adverse effects of biomass fuels use are investigated and this paper adds to the limited pool of evidence in Malawi.

Mishra et al.[13] performed a similar study in Zimbabwe and a statistically significant reduction of 175 g (95% CI -300; -50) in mean birth weight was observed in children born to mothers that used high pollution fuels as compared to low pollution fuels, we observed a similar effect in our study though statistically non-significant. Apart from the Zimbabwean study, there is insufficient literature on maternal exposure to biomass fuels and reduction of birth weight in sub-saharan Africa, where the population is expected to use more biomass fuels and at the same time record higher birth rates. We also observed an increased but insignificant risk of reduced birth weight in children categorized as below average on birth as compared to children categorized as average and above. According to the 2010 DHS report,[16] size at birth is a good proxy for child birth weight which might explain the consistent results between the use of measured birth weight and categories of size at birth. An Indian study[12] on association between biomass fuel use and maternal report of child size at birth also based on DHS data, found an increased risk of reduced birth weight based on the size of child at birth OR (95% CI)1.07 (0.94, 1.22), though non-significant after adjustment for child, maternal and household risk factors which is similar to what we observed in our study. The RESPIRE trial in a Guatemala[7] investigated the effect of chimney stoves in reducing the occurrence of low birthweight. It was observed in this study that on average, infants born to mothers who used a stove weighed 89 g (95% CI, –27;204) more than infants whose mothers used open fires and after confounder adjustment risk of low birth weight was OR (95% CI) 0.74 (0.33–1.66) however insignificant consistent with the current analysis. As much as the methodology used in performing these studies were similar, the adjustment variables used, as well as the exposure assessment are different, as such direct comparability of our study to the above-mentioned studies is limited.

It is imperative that our results be interpreted under a set of limitations. Firstly, this study was a cross-sectional study also conducted as a secondary analysis from data previously collected as part of the DHS surveys. Apart from the reliance of self-reports, both on the outcome and exposure, the cross-sectional design poses problems in establishing the temporal link between exposure and outcome. Our analysis assumes that maternal exposure to biomass fuels occurred before birth which might not always be the case. In addition, multiple families do not exclusively use one type of cooking fuel, with unpredictable power outages, it is most likely that families switched between different types of cooking fuel at the time of survey and recording of birthweight as such this might result in exposure misclassification and therefore an underestimated effect. We also used the recalled outcome from mothers both with birth weight and size at birth; this might introduce recall bias in the analysis and have implications on results. We observed a lower reduction in birthweight for measurements that were recalled than those obtained from health cards which might suggest mothers could overestimate their child's weight at birth if they are asked to recall and this may underestimate the true effect estimate. Another limitation of this study is that we do not adjust for exposure to tobacco smoke exposure which is a known risk factor for reduced birth weight, however in our current population the prevalence of maternal smoking is very low and therefore we do not think it would contribute significantly to explaining the relationship between reduced birth weight and cooking fuel type. We also do not adjust for iron supplements and malarial medication received by the mother during pregnancy because these were only available for the most recent birth. Using these variables would have reduced our sample size considerably to make any meaningful comparison between the two groups of fuel users as households using low pollution fuels were already substantially lower in the current population. In line with that, the lack of statistical significance in this study could be attributed to lack of statistical power to observe an effect of the exposure. Exclusion due to either lack of outcome or exposure data led to loss of a good proportion of the data which might have led to power loss. An association between proximity to heavily used roads and low birth weight has also been suggested,[17] we did not adjust for this as this information is unavailable in the DHS datasets. Based on the above adjustment limitations, we cannot rule out any residual confounding. Finally, as compared to the study population, there were substantially more children with low birth weight in the excluded population. This could have also potentially led to underestimation of the true effects of exposure on the outcome.

The strength of this study is that the DHS datasets are characterized by good data quality as a result of standardized approaches to sampling, data collection and data entry, which have benefited from improvements over time, and are characterized by high response rates.[18] In addition, it incorporates a representative sample of the Malawian population which makes it more reliable to generalize results to the general Malawian population. To our knowledge, this is the first study that has investigated effects of use and therefore exposure to biomass fuels on reduced birth weight in Malawi. Adverse effects of biomass fuels in the Malawian population have been reported in women such as shortness in breath[3] and reduced lung function in adults.[19] A more recent intervention study, the CAPS study investigated the effect of an improved gas stove on child pneumonia rates but no study has focused on pregnancy outcomes such as birth weight.

The effects of biomass fuels on birth weight are multifactorial.[5] Indoor air smoke releases carbon monoxide and particles. The particles released may induce or precipitate maternal lung disease. This coupled with carbon monoxide will reduce the maternal content of partial pressures of oxygen subsequently impairing oxygen delivery to the placenta. This then impairs foetal growth and leads to the low birth weight in the babies born to mothers exposed to biomass fuels.[5,7]

Use of biomass fuels in Malawi is on the rise day by day and the evidence suggesting negative health effects makes it an area of public health concern. More carefully designed studies and conveniently longitudinal studies that can objectively assess exposure to high pollution fuels can be conducted to further investigate the effect of biomass fuels on reduced birth weight and other pregnancy outcomes.

Conclusions

We consistently observed a reduction in birth weight in children born to mothers that biomass fuels such firewood, charcoal, dung, straw and crops as compared to mothers that use low pollution fuels such electricity, LPG and biogas. We, however, did not observe significant associations. It is essential to establish solid evidence of effects of biomass fuel use for the Malawian population in order to inform policy and strengthening advocacy for using alternative fuels especially for expectant mothers and in general inform on the adverse effects of environmental exposures on health.

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Competing interests

All authors declare that they have no competing interests related to this work. This study was carried out without any funding support.

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