Understanding the association between gradient of cooking fuels and low birth weight in India

Samarul Islam, M.Phil [*], Sanjay K Mohanty, Ph.D

International Institute for Population Sciences (IIPS), Mumbai, India

ABSTRACT

Background: Birth weight is positively associated with physical and cognitive development of children and adversely associated with the use of unclean cooking fuels. Though studies have examined the contextual determinants of birth weight, no attempt has been made to understand the association of gradient of cooking fuels with birth weight in India. The objective of this paper is to understand the association of type of cooking fuel with low birth weight in India.
Methods: Unit data from the fourth round of the National Family Health Survey (NFHS) (2015–16), covering 8206 singleton births from four states of India, was used in the analysis. These states reported more than 80% of birth weights by way of health cards issued by a public authority. Linear regression analysis was used to estimate mean birth weight, adjusting for confounders. We computed a new wealth index, excluding electricity and cooking fuels, using principal component analysis to capture the economic gradient of cooking fuel.
Results: Our results suggest a strong gradient of cooking fuels on mean birth weight. The adjusted mean birth weight in households using electricity was 2957 g (95% CI: 2939–2975). It was 2908 g (95% CI: 2907–2910) for LPG, 2792 g (95% CI: 2784–2801) for biogas, 2819 g (95% CI: 2809–2829) for kerosene, 2841 g (95% CI: 2816–2866) for coal/lignite/charcoal, and 2834 g (95% CI: 2831–2836) in households using biomass. A difference of 165 g in predicted mean birth weight was found among children born in households that used electricity in relation to those that used biogas. The difference in relation to kerosene, coal/lignite/charcoal, and biomass was 138 g, 116 g, and 123 g respectively. Significant differences in mean birth weight were also observed by wealth quintiles, mother's underweight, social groups, birth interval, and mother's anemia status.
Conclusion: Findings from the study suggest to strengthen the policies on access to clean fuels and meet the interconnected goals of sustainable development.

1. Introduction

Increase in access to clean cooking fuels (CCF) – such as liquefied petroleum gas (LPG), biogas, and electricity – is a prerequisite for achieving energy-related and other inter-connected sustainable development goals (SDGs), including good health and wellbeing (Rosenthal et al., 2018). The progress in attending universal access to clean energy is largely slow and uneven across and within countries (ESMAP, 2020). Globally, 4 billion people don't have access to clean cooking fuels and technologies. While 2.75 billion have no access, 1.25 billion are in transition to clean fuels, with great regional, country-wide and rural-urban variations (ESMAP, 2020). The use of unclean cooking fuels (UCF) – comprising wood, crop residues, dung cakes, coal, and kerosene – for cooking is a major source of household air pollution (HAP) in

developing countries (Balakrishnan et al., 2013; Bartington et al., 2017; Clark et al., 2010; Fullerton et al., 2008; Junaid et al., 2018; Rupakheti et al., 2019).

Studies suggest that HAP concentrations far exceed ambient air pollution concentrations and that indoor air concentrations of PM, CO, and NO2 are beyond the World Health Organisation's permissible levels in many countries (Balakrishnan et al., 2013; Bartington et al., 2017; Junaid et al., 2018; Mukhopadhyay et al., 2012; Rupakheti et al., 2019). The impact of HAP is exacerbated by the lack of ventilation or chimneys in homes, the absence of a separate kitchen, and the use of poor stoves (Martin et al., 2014; Naz et al., 2017; Thompson et al., 2011). The sources, pollutants, and extent of HAP are the result of complex interactions between housing structures, household use of appliances, type of fuel used, behavioural factors, humidity, and outdoor

environment and practices (Balakrishnan et al., 2004; Clark et al., 2010; Héroux et al., 2010; Jiang & Bell, 2008; Rupakheti et al., 2019). HAP is a leading environmental risk factor for the global burden of disease (Gakidou et al., 2017). Recent estimates suggest that exposure to HAP from the burning of UCF was responsible for 2.31 million deaths (4.1% of all global deaths) and 91.5 million DALYs (3.6%) globally in 2019, most of these deaths having occurred in low- and middle-income countries of Asia and Africa (HEI, 2020). Cooking with traditional and polluting fuels costs the world $2.4 trillion each year and has an adverse impact on health ($1.4 trillion), climate ($0.2 trillion), and women ($0.8 trillion from lost productivity) (ESMAP, 2020).

A large body of literature has documented the impact of HAP from the burning of UCF on adverse pregnancy outcomes, child health, and malnutrition (Amegah et al., 2014; Epstein et al., 2013; Islam et al., 2020; Khan et al., 2017; Kim et al., 2011; Pope et al., 2010; bib_-Smith_and_Pillarisetti_2017Smith & Pillarisetti, 2017; Tielsch et al., 2009; Torres-Duque et al., 2008). Women from developing countries get exposed to HAP for an average of almost 3 h while cooking at home, with pregnant women spending more time at home (Barnes & Sen, 2004; Boy et al., 2002 Klepeis et al., 2001). Exposure to harmful pollutants emitted by UCF has a serious impact on the health of women and children (Amegah et al., 2014; Epstein et al., 2013; Fullerton et al., 2008; Smith & Pillarisetti, 2017; Tielsch et al., 2009). Several studies have found an adverse effect of HAP on pregnancy outcomes, including stillbirths, preterm births, and low birthweight (LBW), in various geographical settings (Amegah et al., 2014; Balakrishnan et al., 2018; Epstein et al., 2013; Khan et al., 2017; Pope et al., 2010; Tielsch et al., 2009; Wylie et al., 2014; Yucra et al., 2014). Specifically, studies suggest that maternal exposure to biomass smoke during pregnancy may decrease birthweight and increase the risk of LBW (Amegah et al., 2014; Epstein et al., 2013; Jiang et al., 2015; Khan et al., 2017; Milanzi et al., 2017; Mishra et al., 2004; Pope et al., 2010; Thomson et al., 2011; Tielsch et al., 2009; Wylie et al., 2014).

Low birth weight (LBW), defined as birth weight <2,500 g, is the strongest predictor of a child's physical health (Belbasis et al., 2016; Johnson & Schoeni, 2011). In 2014, 20 million births, accounting for 15% of all births, were LBW worldwide (WHO, 2019). Children with LBW are more likely to succumb to death (Bernstein et al., 2000; Horbar, 2002). LBW has numerous consequences, including stunting and poor growth (Aryastami et al., 2017; Rahman et al., 2016), poor cognitive and neurobehavioral development (Du et al., 2020; Ha et al., 2014), asthma (Brooks, 2001), diabetes (Huang et al., 2019; Curhan et al., 1996), autism spectrum disorders (Talmi et al., 2020), hypertension, and obesity (Curhan et al., 1996).

Despite four decades of governmental commitment to expanding the use of CCF, over half of the households in India still do not use CCF (IIPS and ICF, 2017). Of all the Indian households, 41% use wood, 7% animal dung, 3% agricultural crop, and 3% straw/shrubs/grass (IIPS and ICF, 2017). In India, HAP contributed to 30% of ambient PM 2.5, 0.61 million premature deaths and 20.9 million DALYs (Chowdhury et al., 2019; Pandey et al., 2020). Concomitantly, India performed poorly on child health, with 18% of children having a LBW, 38% being stunted, and 59% being anemic (6–59 months) (IIPS and ICF, 2017).

LBW is a major public health challenge in India and is associated with poor physical and cognitive development of children (Du et al., 2020; IIPS and ICF, 2017; Ha et al., 2014). Existing studies have examined the variations in and determinants and contextual factors of birth weight (Balakrishnan et al., 2018; Boy et al., 2002; Epstein et al., 2013; Jiang et al., 2015; Khan et al., 2017; Milanzi et al., 2017; Siddiqui et al., 2008; Thompson et al., 2011; Tielsch et al., 2009; Wylie et al., 2014; Yucra et al., 2014). However, few attempts have been made to understand the association between the gradient of cooking fuels and birth weight in India (Epstein et al., 2013; Wylie et al., 2014). This is primarily because birth weight of children is not recorded at the time of the survey. There are several other reasons, which include home-based delivery, low level of literacy, lack of awareness, etc. It is only

recently that there has been an increase in the reporting of birth weight information by way of vaccination or health cards (written cards) in some states of India. In this context, we explored an important research question: "Is fuel type associated with birthweight in India?" We explored the association of cooking fuels with birth weight in states that had recorded over 80% of the birth weights on health cards. We hypothesized that mothers in households using UCF are exposed to smoke during pregnancy, which adversely impacts the birth weight of the baby. This is the first-ever Indian study that explores the association between specific cooking fuels and birth weight, as recorded on written cards, using population-based survey data.

2. Data and methods

Data from the fourth round of the National Family Health Survey (NFHS- 4), conducted during 2015–16, was used for this study. NFHS-4 is the fourth in the series that provides information on fertility, contraception, maternal care, nutrition, and other health aspects for states/union territories and districts of India. NFHS surveys use standardized questionnaires, sample designs, and field procedures to collect data. Three schedules, namely household schedule, women's schedule, and men's schedule were canvassed. The information in NFHS-4 was collected from a nationally representative sample of 601,509 households, 699,686 women (aged 15–49 years), 103,525 men (aged 15–54 years), and 259,627 children (aged 0–5 years). The details of the survey, including the objectives, scope, sample size, design, and sampling instrument can be found in the NFHS report (IIPS and ICF, 2017). We used household and kids' files for the analysis, whereas the information came from the household and women's schedules. The analysis was carried out only for the states that had recorded more than 80% of the birth weights on health cards. These include Kerala, Karnataka, Puducherry, and Tamil Nadu. In our analysis, only singleton births born with 9 or more months of gestation during three years prior to the survey were considered. The total sample for our study was 8602 births across these states of India.

2.1. Outcome variable

In this study, the outcome variable was birth weight. Birth weight is a numerical value that is recorded at the time of birth, mostly from deliveries conducted at health centres. The question on birth weight was asked at the time of the survey and the information recorded accordingly. Field investigators were trained to record the birth weight if a woman showed the health card – a card that notes the immunisation record of a child along with its weight at the time of birth. Such cards are issued by the health centres in India at the time of birth. Birth weight can be categorized into low birth weight, defined as births with a reported weight less than 2500 g and normal birth weight, defined as weight 2500 g or more at birth. We restricted our analysis to birth weight – which is a numerical measure – as against birth size and birth weight from mother's recall, which is more of a subjective measure.

2.2. Exposure variable

The main exposure variable in our study was cooking fuels. NFHS-4 collected information on the main cooking fuel used for cooking in the households, the fuels being electricity, LPG/natural gas, biogas, kerosene, coal/lignite, charcoal, wood, straw/shrubs/grass, agriculture crop waste, and animal dung. Fuels are classified as clean and unclean, based on their impact on human health. Clean cooking fuels (CCF) include electricity, LPG/natural gas, and biogas, while unclean cooking fuels (UCF) include coal/lignite, charcoal, wood, straw/shrubs/grass, agricultural crop waste, and dung cakes.

2.3. Confounders

We included explanatory variables at the child, mother and household levels. We selected the confounders after an extensive review of existing literature (Balakrishnan et al., 2018; Epstein et al., 2013; Jiang et al., 2015; Khan et al., 2017; Milanzi et al., 2017; Mishra et al., 2004; Sreeramareddy et al., 2011; Thompson et al., 2011; Tielsch et al., 2009; Wylie et al., 2014). At the child level, the confounders selected were sex of the child (Male and Female) and birth order (First, Second, Third, and Four or more). At the mother level, birth interval (First birth, 0–24 months, 25+ months), mother's age at childbirth (<20, 20–29, and 30+), mother's underweight (No and Yes), mother's anemia status (Not anemic, Mildly anemic, and Severely anemic), antenatal care visits during pregnancy (0, 1–3 and 4+), mother's education (No education and Primary, Secondary, and Higher), mother's social group (Scheduled Tribe, Scheduled Caste, Other Backward Castes, and Other), and environmental tobacco smoke (No and Yes) were selected as the variables. Wealth index (Poorest, Poorer, Middle, Richer, and Richest) and place of cooking (in the house with separate kitchen, in the house without separate kitchen, in a separate building, and outdoors) were the variables selected at the household level. NFHS (the Indian version of DHS) does not collect information on income and household expenditure. Therefore, wealth index was used as a proxy measure for household economic status. Several studies have used wealth index as a proxy for economic status (Islam et al., 2020; Khan et al., 2017). The index is a composite score of a diverse range of household assets such as land, housing conditions, household amenities and assets, and presence of domestic servants. Details of the index can be found elsewhere (IIPS and ICF, 2017). Place of residence and states were also considered in the analysis.

2.4. Statistical analysis

To examine the association between cooking fuel and birth weight, we performed descriptive statistics, bivariate analysis with socioeconomic and demographic characteristics. Furthermore, we used linear regression, controlling the confounders and estimating mean birth weight. As the wealth index includes a household's access to electricity and cooking fuels, we computed a new wealth index excluding electricity and cooking fuels, following a similar methodology. The wealth index was generated through the principal component analysis and grouped into five quintiles. We calculated the index at the state level to account for heterogeneity and differences in economic status across the states in India. The STATA 16.0 software was used for analysing the data.

3. Result

Fig. 1 presents the per cent distribution of birth weight across the states of India. Birth weight in India was recorded for 44% of children on a health card. For 34% children, birth weight was recorded from mother's recall, while 22% children were not weighed (includes don't know and special answer). The national average conceals the large variations in the reporting of birth weight across the states of India. Reporting of birth weight through written cards varies from as low as 13% in the state of Uttar Pradesh to as high as 89% in Puducherry. Reporting of birth weight from health cards has been improving with increase in institutional deliveries. The states of Kerala, Puducherry, Tamil Nadu, and Karnataka had more than 80% of birth weights recorded on health cards. Institutional delivery is also very high in these states.

Table 1 presents the mean birth weight of full-term singleton children and the percentage of households by the type of cooking fuels in four states of India. Almost 60% of the households used LPG/gas as the primary cooking fuel, 36% reported using biomass, 2% biogas, 2% kerosene, 0.7% electricity, and 0.4% coal/lignite/charcoal. Among the sample households, 95% used LPG/gas and biomass as the primary cooking fuels. The state of Puducherry reported the highest per cent of LPG/gas use at 77%, followed by Tamil Nadu (67%). Karnataka reported 49% of LPG/gas use, which was the lowest among all the states. There was a significant difference in the use of cooking fuels across the socioeconomic characteristics of the households, including place of residence, social groups, wealth quintiles, mother's education, birth order, and place of cooking. LPG/gas use was low among households belonging to the poor wealth quintiles, those belonging to a scheduled tribe/caste, among mothers with no education, and among those residing in rural areas. Households in rural areas were more likely to use biomass as the primary cooking fuel, whereas LPG/gas was the dominant cooking fuel
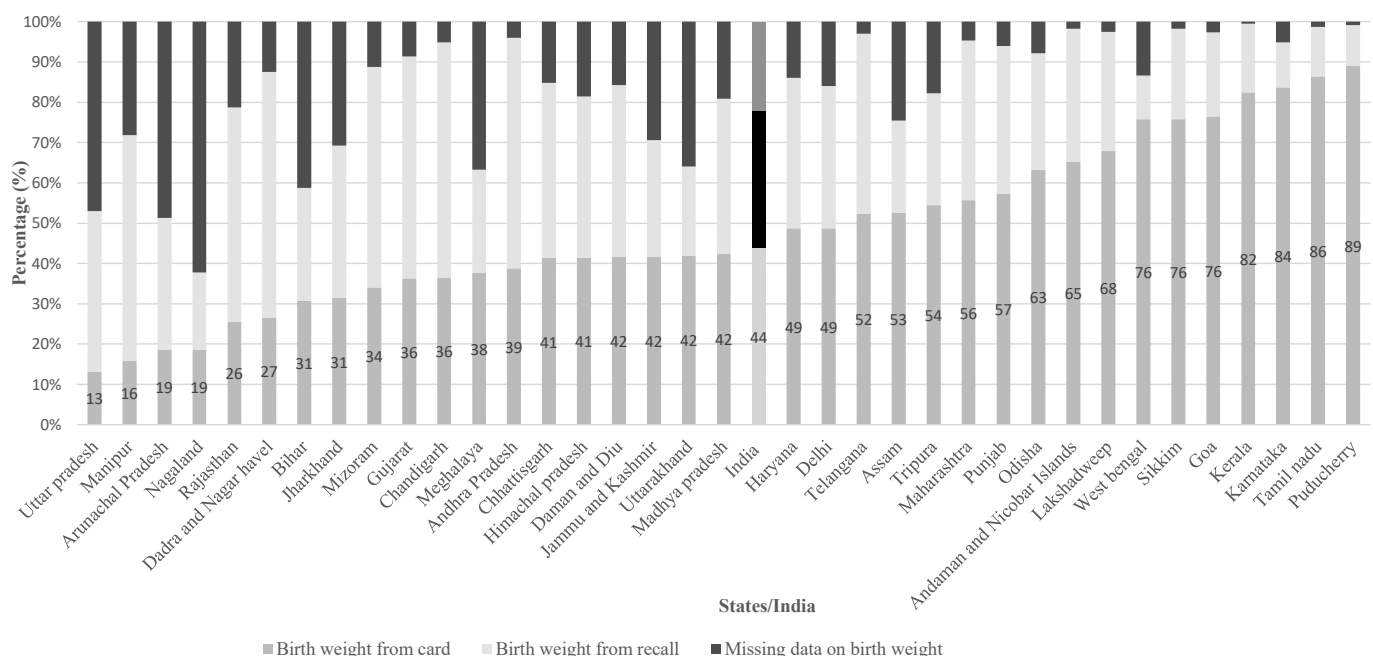

Fig. 1. Percentage of children born in the last five years according to the source of birthweight across the states of India, 2015–2016.

Table 1

Mean birthweight of full-term singleton children born in the last 3 years and percentage of households using LPG/gas as cooking fuels by selected socio-demographic characteristics, 2015–16.

Socio-demographic characteristics	Mean birth weight	Electricity	LPG/gas	Biogas	Kerosene	Coal/lignite/charcoal	Biomass	Unweighted N
Cooking fuels								
Electricity	2967							66
LPG/Gas	2899							4706
Biogas	2743							166
Kerosene	2825							163
Coal/lignite/charcoal	2872							43
Biomass	2832							3458
Place of cooking								
In the house with separate kitchen	2894	0.6	68.1	2.1	0.8	0.4	28.0	1397
In the house without separate kitchen	2825	1.8	50.0	2.3	6.0	0.3	39.5	5836
In separate building	2869	0.3	53.9	5.5	2.2	0.1	37.9	647
In outdoor	2766	0.1	1.62	0.1	1.21	1.0	96.0	722
Environmental tobacco smoke								
No	2867	0.7	58.6	2.0	1.6	0.5	36.7	5487
Yes	2877	0.8	58.9	2.7	2.1	0.3	35.3	3115
Sex of child								
Male	2906	0.7	59.8	2.2	1.6	0.5	35.3	4348
Female	2834	0.7	57.7	2.2	1.9	0.3	37.1	4254
Birth order								
First	2857	0.5	62.0	1.9	1.7	0.4	33.6	3964
Second and third	2883	0.8	57.0	2.6	1.8	0.4	37.4	4365
Four or more	2876	2.1	35.1	1.4	3.4	0.0	58.1	273
Birth interval								
First births	2857	0.5	62.0	1.9	1.7	0.4	33.6	3964
0–24 months	2858	0.8	49.2	2.6	2.2	0.6	44.6	1344
25+ months	2892	0.9	58.6	2.5	1.7	0.3	35.9	3294
Mother's age at child's birth								
<20	2846	0.5	53.1	1.5	2.4	0.5	42.0	1198
20–29	2875	0.7	59.5	2.4	1.7	0.4	35.3	6560
30–49	2868	0.9	60.8	1.7	1.7	0.3	34.6	844
Mother underweight								
No	2887	0.7	61.0	2.2	1.7	0.4	34.1	7258
Yes	2776	0.8	45.5	2.1	2.4	0.6	48.6	1344
Mother's anemia status								
Not anemic	2878	0.8	59.3	2.0	1.7	0.4	35.9	4350
Mild	2873	0.8	59.0	2.6	1.7	0.3	35.6	3263
Severe and moderate	2833	0.3	55.9	2.1	2.3	0.5	38.9	989
Antenatal care during pregnancy								
0	2857	0.5	55.4	1.5	2.1	0.4	40.0	1398
1–3	2841	1.0	58.8	1.5	1.9	1.1	35.6	914
4+	2878	0.7	59.5	2.5	1.7	0.3	35.3	6290
Mother's education								
No education and primary	2822	1.4	32.5	0.9	2.7	0.8	61.6	1311
Secondary	2855	0.6	57.4	2.1	2.0	0.4	37.4	5479
Higher	2943	0.6	78.5	3.3	0.4	0.1	17.2	1812
Social groups								
Schedule tribe and schedule caste	2806	0.8	41.9	2.7	2.8	0.5	51.4	2598
Other backward caste	2892	0.8	66.5	2.3	1.5	0.3	28.8	4973
Other[a]	2923	0.5	61.5	0.9	0.8	0.6	35.8	1031
Wealth quintile								
Poorest	2804	1.0	17.6	1.1	3.5	0.8	76.1	1408
Poorer	2838	0.5	39.0	1.7	3.0	0.7	55.2	1847
Middle	2858	1.1	57.1	2.1	2.0	0.3	37.5	1885
Richer	2880	0.6	75.4	3.0	0.8	0.3	19.9	1840
Richest	2950	0.5	90.1	2.8	0.3	0.0	6.3	1622
Place of residence								
Urban	2888	0.7	77.6	2.7	1.9	0.1	17.0	3361
Rural	2857	0.7	44.3	1.9	1.7	0.6	50.8	5241
States								
Karnataka	2859	0.8	48.7	0.8	1.4	0.9	47.5	3200
Kerala	2942	0.4	51.3	0.1	0.3	0.0	48.0	1029
Puducherry	2993	2.3	76.9	6.8	0.7	0.0	13.2	530
Tamil Nadu	2857	0.7	66.7	3.6	2.4	0.2	26.4	3843
Total	2871	0.7	58.7	2.2	1.8	0.4	36.2	8602

Note-.

Data source - National Family Health Survey - 4 (2015–16).

[a] Other caste includes other than ST/SC, other backward caste.

in urban areas. Households primarily using biomass were mostly from the poor wealth quintiles, belonged to scheduled tribes/castes, had mothers with no education, and cooked food outdoors.

The mean birth weight of children varied significantly by cooking fuels. The lowest mean birth weight of 2,743 g was observed for households using biogas fuels, followed by kerosene (2,825 g) and biomass (2,832 g). Households using electricity reported the highest average birth weight of 2,967 g. Birth weight also varied by place of

cooking, with households cooking outdoors and without separate kitchen reporting the lowest weight of 2,766 g and 2,825 g, respectively, while households cooking in separate kitchen reported the highest weight of 2,894 g. Birth weight of female babies was significantly – almost 75 g – lower than that of male babies. There was a difference of 121 g in mean birth weight among babies born to mothers with no education compared to those born to mothers with higher education. The highest difference in mean birth weight was observed among the poorest and richest wealth quintiles – a difference of almost 150 g. Differences in mean birth weight were also observed by mother's underweight, social groups, birth interval, and mother's anemia status. The state of Tamil Nadu reported the lowest mean birth weight of 2,857 g, while the state of Puducherry reported the highest mean birth weight of 2,993 g.

Table 2 displays the percentage of full-term singleton children born with low birth weight (less than 2,500 g) according to the exposure variables and selected background characteristics. The bivariate analysis clearly shows that across the sub-population categories, the prevalence of LBW was higher in households using UCF, e.g., biomass, kerosene, coal/lignite/charcoal and biogas. This holds true across all the four states. Among all the households, the highest LBW of 19% was observed for biogas, followed by 17% for electricity, 16% for coal, 15% for biomass, and 14% for kerosene, while the lowest LBW of 13% was reported for LPG/gas. Across the exposure variables, the prevalence of LBW was higher in the case of presence of environmental tobacco smoke, female child, first birth child, underweight mother, and mother with no education.

3.1. Potential impact of cooking fuels on birth weight

Table 3 shows the unadjusted and adjusted mean birth weights by type of cooking fuel used in selected states of India. The result suggests that birth weight has a strong gradient with type of cooking fuel. The unadjusted mean birth weight ranged from 2,822 g with the lowest gradient of cooking fuel (kerosene) to 2,957 g with the best cooking fuel (electricity). Even after controlling the socio-demographic covariates, there was a significant difference in mean birth weight by type of cooking fuel. Children born in households using electricity and LPG/natural gas had the highest mean birth weight compared to those born in households using other cooking fuels. The unadjusted predicted mean birth weight was 2,907 g against the adjusted mean (adjusted for socio-economic covariates) weight of 2,908 g (95% CI: 2907–2910) for LPG. Households using biomass had a mean birth weight of 2,833 g and an adjusted mean weight of 2,834 g (95% CI: 2831–2836). Biogas is a clean fuel, but households using biogas reported the lowest mean birth weights of 2,789 g (unadjusted) and 2,792 g (adjusted) (95% CI:2784–2801). Households using kerosene, which is an unclean cooking fuel, had the second-lowest mean birth weights of 2,822 g (unadjusted) and 2,819 g (adjusted) respectively. There was a difference of 165 g in the predicted mean birth weight (adjusted) among children born in households using electricity in relation to those using biogas, a difference of 138 g in relation to kerosene, 116 g for coal/lignite/charcoal, and 123 g for biomass. The pattern held true for the state of Tamil Nadu, where the lowest mean birth weight of 2,790 g was reported for the use of biogas, followed by biomass (2,800 g) and kerosene (2,807 g). Households using electricity as the primary cooking fuel reported the highest mean birth weight of 2,962 g. The difference in the predicted mean birth weights in households using electricity and those using biogas was 172 g, while it was162 g for biomass and 155 g for kerosene.

4. Discussion

This is the first-ever study that examines the association between the type of cooking fuel used and birth weight in India. We used empirical data from four states/union territories that had reported over 80% of the birth weights and recorded them in a health card – an authentic

Table 2

Percentage of full-term singleton children born low birth weights (weight less than 2500 g) according to exposure variables and selected background characteristics, 2015–16.

Socio-demographic characteristics	LPG/ Gas	Electricity	Biogas	Kerosene	Coal	Biomass
Place of cooking						
In the house with separate kitchen	12.8	13.9	22.9	16.3	15.2	13.0
In the house without separate kitchen	14.0	19.3	18.6	14.7	23.9	15.1
In separate building	13.6	56.4	3.4	13.5	49.4	12.3
In outdoor	26.3	0.0	0.0	0.0	12.2	19.3
Environmental tobacco smoke						
No	13.6	8.3	11.9	15.1	10.7	14.9
Yes	12.1	29.2	27.1	13.1	33.4	14.2
Sex of child						
Male	10.9	8.6	19.2	14.1	8.5	14.1
Female	15.2	25.2	18.2	14.4	27.6	15.2
Birth order						
First	12.4	35.3	16.3	16.8	NA	17.1
Second and third	13.4	8.4	19.6	12.5	25.0	12.6
Four or more	19.0	0.0	40.0	9.5	10.0	15.0
Birth interval						
First births	12.4	35.3	16.3	16.8	25.0	17.1
0–24 months	14.5	15.5	15.0	15.5	7.0	13.1
25+ months	13.4	4.5	22.4	10.5	12.1	12.7
Mother's age at child's birth						
<20	15.1	0.0	15.3	25.1	0.0	14.4
20–29	12.4	19.6	18.7	13.2	21.8	14.6
30–49	14.8	13.2	23.2	0.0	0.0	15.9
Mother underweight						
No	12.7	17.8	17.4	14.2	18.2	14.0
Yes	15.7	11.8	27.1	14.3	10.3	17.7
Mother's anemia status						
Not anemic	12.9	24.2	22.7	9.7	13.8	14.7
Mild	12.5	10.1	16.4	15.8	4.7	14.3
Severe and moderate	14.8	0.0	11.8	24.0	47.4	15.6
Antenatal care during pregnancy						
0	13.7	12.6	21.2	13.8	11.6	15.6
1–3	14.9	1.2	27.1	7.7	8.7	19.6
4+	12.6	20.5	17.6	15.4	22.7	13.7
Mother's education						
No education and primary	16.5	20.9	34.4	3.9	18.9	15.6
Secondary	13.5	11.9	17.1	16.8	9.3	14.8
Higher	11.2	26.2	18.9	20.9	0.0	12.0
Social groups						
Schedule tribe and schedule caste	17.5	24.4	27.3	11.6	31.4	15.9
Other backward caste	11.7	12.8	11.3	15.2	2.5	14.7
Other1	12.5	20.2	46.8	28.4	17.9	10.2
Wealth quintile						
Poorest	20.6	12.3	12.7	17.0	19.4	14.7
Poorer	13.9	26.0	21.7	16.6	22.4	14.0
Middle	15.4	22.0	17.0	9.9	0.0	14.6
Richer	13.5	9.1	11.7	7.6	14.6	16.6
Richest	9.7	11.9	27.6	15.5	NA	14.2
Place of residence						
Urban	13.4	21.0	18.9	11.3	9.0	14.9
Rural	12.5	13.8	18.4	16.7	17.8	14.6
States						
Karnataka	14.8	9.3	39.3	9.8	11.3	13.2
Kerala	9.7	41.6	NA	NA	NA	10.7
Puducherry	13.2	5.6	NA	NA	NA	12.0
Tamil Nadu	12.9	19.6	16.4	16.4	29.5	18.3
Total	13.0	16.9	18.7	14.3	16.4	14.7

Note-.

[1]Other caste includes other than ST/SC, other backward caste.

Data source - National Family Health Survey −4 (2015–16).

Table 3
Unadjusted and adjusted mean birthweight (in gram) of full-term singleton children born in last 3 years by cooking fuel types, 2015–16.

Cooking fuels	Unadjusted Mean birth weight	Adjusted			Difference in mean birthweight (adjusted) from electricity and other cooking fuels)
		Mean birth weight	95% CI		
			L	U	
Total					
Electricity	2957	2957	2939	2975	
LPG/Gas	2907	2908	2907	2910	48
Biogas	2789	2792	2784	2801	165
Kerosene	2822	2819	2809	2829	138
Coal/ lignite/ charcoal	2834	2841	2816	2866	116
Biomass	2833	2834	2831	2836	123
Tamil Nadu					
Electricity	2957	2962	2938	2986	
LPG/Gas	2907	2892	2890	2894	70
Biogas	2789	2790	2782	2798	172
Kerosene	2822	2807	2797	2818	155
Coal/ lignite/ charcoal	2834	2837	2804	2871	125
Biomass	2833	2800	2797	2803	162

Note-.
Place of kitchen, child's sex, birth order, birth interval, mother's age at birth, mother's underweight, mother's anemia status, antenatal care, mother's education, social groups, religion, wealth index, place of residence, states have been included in the adjusted in the model.
Bold mark shows coefficient significant at 5% (P < 0.05). L and U stands for lower and upper limit respectively with 95% Confidence Interval (CI).
Data source: National Family Health Survey −4 (2015–16).

document that records the birth weight of children. While earlier studies had focused on birth size and not birth weight (particularly as recorded on health cards) due to incompleteness of information, we used the numerical measure of birth weight recorded at the time of birth and certified by a health authority. The few studies that did consider birth weight, relied on mother's recall of child's birth weight, which is prone to error. Our approach of understanding the association of gradient of cooking fuels with birth weight, as recorded on health cards, provides robust results for an evidence-based policy, given the high prevalence of low birthweight (IIPS and ICF, 2017).

The following are the salient findings of the study. Our result suggests a clear gradient of the effects of cooking fuels on mean birth weight. Households using UCF, such as coal/lignite, kerosene, wood, animal dung, and straw/shrubs/grass, had significantly lower birth weights compared to those using CCF such as electricity and LPG/natural gas. This result held true even after controlling the socio-economic covariates. Our results are similar to those of the previous studies that have explored the association between cooking fuels and birth weight in low middle income countries including India (Balakrishnan et al., 2018; Khan et al., 2017; Milanzi et al., 2017; Jiang et al., 2015; Wylie et al., 2014; Epstein et al., 2013; Sreeramareddy et al., 2011; Thompson et al., 2011; Tielsch et al., 2009; Siddiqui et al., 2008; Mishra et al., 2004; Boy et al., 2002). Unlike previous studies in India (Epstein et al., 2013; Sreeramareddy et al., 2011; Tielsch et al., 2009), a study in Zimbabwe (Mishra et al., 2004) used birth weight information from mother's recall as well as health cards. The study had a selection bias as households using UCF, those belonging to poor wealth quintiles, and those located in rural areas were not likely to have birth weight information. In our study, we used birth weight data from health cards alone to assess the role of specific cooking fuels on low birth weight. Previous studies that used DHS data had the possibility of correlation effect of household wealth index, as the wealth index used in DHS includes cooking fuels and electricity (Epstein et al., 2013; Khan et al., 2017; Milanzi et al., 2017; Sreeramareddy et al., 2011). For our study, we computed a new

wealth index that excluded cooking fuels and electricity, using a methodology similar to the DHS methodology of computing the wealth index.

A meta-analysis by Amegah et al. (2014) found that solid fuels are associated with a 35% increased risk of LBW (EE-1.35, 95% CI: 1.23, 1.48) as well as an 86 g reduction in birthweight, a finding similar to the ones reported by other meta-analyses by Kim et al. (2011) and Pope et al. (2010). Babies born to mothers using solid fuels are lighter than those born to mothers using CCF (Mishra et al., 2004; Sreeramareddy et al., 2011; Wylie et al., 2014). Women who are exposed to biomass are associated with a 49% increased risk of LBW (Tielsch et al., 2009). A birth cohort study in China found that biomass was associated with a more than two-fold increase in LBW (OR-2.51, 95% CI: 1.26, 5.01) (Jiang et al., 2015). The association between LBW and maternal exposure to HAP from the burning of UCF was first explored in Guatemala by Boy et al. (2002). It was then explored in other parts of the developing world (Balakrishnan et al., 2018; Epstein et al., 2013; Khan et al., 2017; Thompson et al., 2011; Tielsch et al., 2009).

The study results published by Epstein et al. (2013) indicated that household use of biomass fuels was significantly associated with increased odds of LBW (OR-1.57; 95% CI: 1.03–2.41 for coal, OR- 1.51; 95% CI: 1.08–2.12 for kerosene, OR- 1.24; 95% CI: 1.04–1.48 for biomass) and reduced birth weight (−110 g for coal, −107 g for kerosene, and −78 g for biomass). Another study (Wylie et al., 2014) found that women who used wood as the primary cooking fuel had 112 g lighter infants compared to the gas users. Previous studies on HAP have explored the health impact of clean vs unclean fuels (Jiang et al., 2015; Khan et al., 2017; Milanzi et al., 2017; Mishra et al., 2004; Sreeramareddy et al., 2011), ignoring the impact of individual fuel types. Evidence shows that pollution from the combustion of wood, coal, and kerosene is higher than from the use of LPG/gas and electricity. Since the level of pollutants varies widely for different fuel types, a dichotomous classification of cooking fuels may lead to a misclassification (Balakrishnan et al., 2011).

The conclusion that the use of UCF (biomass, kerosene, coal) is associated with an increased risk of poor birth weight has been consistent in the scholarship of cooking fuels and birth weight. Solid fuels emit a complex mixture of pollutants comprising more than 200 chemicals and compound groups (Torres-Duque et al., 2008). Particular matter (PM), sulphur dioxide, (SO_2), and nitrogen oxide (NO_2) are three pollutants responsible for most of the air pollution and the resultant damage to the environment; the other air pollutants are carbon monoxide (CO) and polyaromatic hydrocarbons (PAH) (Bartington et al., 2017; Bhargava et al., 2004). Fine particulate matter (PM) is the most damaging to human health and is associated with a range of illnesses (Balakrishnan et al., 2018). Particular matter (PM) enters the body through breathing and can cause serious health problems. The biological mechanisms through which HAP or pollutants affect the birth weight of children can be found elsewhere (Amegah et al., 2014; Jiang et al., 2015; Siddiqui et al., 2008).

Our findings have a significant relevance in the existing literature as well as in the implementation of the policies and programs aimed at achieving the SDGs and nutrition targets of the World Health Assembly (WHA) given that India contributes more than the global prevalence of low birth weight (UN, 2016); WHO, 2014, pp. 1–6). We found that over half of the households use UCF and that its use is high (about 80%) among the poor, among those living in rural areas, and among women with no education (IIPS and ICF, 2017). The Government of India has initiated several programs for improving health, including child health, like the National Health Mission (MoHFW, 2013; NRHM, 2005), and has also introduced programs to promote the use of CCF in the last one decade, including the Rajiv Gandhi Gramin LPG Vitaran Yojana (RGGLY), Pratyaksh Hanstantrit Labh (PAHAL), and Give it Up (Manjula & Gopi, 2017). However, the programs have not been successful in achieving the desired goals. The existing scholarship on the use of CCF suggests that poverty and low levels of education are the leading factors behind the use of UCF and that various supply and demand factors play

an important role (Kar et al., 2019; Khandelwal et al., 2017; Sankhyayan & Dasgupta, 2019). The launch of the Pradhan Mantri Ujjwala Yojana, 2016, however, is a great step in the direction of achieving universal use of CCF and reducing the burden of HAP (PIB, 2016).

5. Limitations

Our study has a few limitations. We analyzed only four states of India (accounting for 14% of India's population) – where the coverage of birth weight was over 80% – and excluded many other states. Second, we used cross-sectional data, with inherent limitations in the study design. We considered only those birth weights which had been recorded in a health card; therefore, we excluded a significant per cent of births from our analysis. Third, due to data limitation, we were unable to measure the duration of cooking and the length of exposure to HAP. The concentration of pollutants depends on ventilation, type of stove used for cooking, season of cooking, and housing characteristics, all of which act as a measure of personal exposure to smoke in the house. In our study, we were also unable to account for the use of mixed fuels or the practice of fuel stacking due to data limitations. Despite the above limitations, the findings are consistent with other studies and delineate the association of birth weight with the use of clean fuels in India.

6. Conclusion and policy implications

The findings of the study will help strengthen the policies on access to CCF and meet the World Health Assembly nutrition target to reduce the prevalence of LBW by 30% between 2012 and 2025. It will boost the efforts aimed at achieving a) SDG 3.2, which aims at reducing neonatal mortality to 12 per 1000 live births and under-five mortality to 25 per 1000 live births, b) SDG 2.2 aimed at ending all forms of malnutrition in under-five children, and c) SDG 3.9, which aims to reduce the number of deaths and illness from pollution. It is crucial to address the challenges associated with cooking, especially in rural areas, where 69% of India's population lives, and where inefficient, polluting, traditional fuels are used for cooking. While a majority of the people in the rural areas of the world's poorest countries are at the risk of exposure to cooking smoke, this is increasingly becoming a problem of the poor urban dwellers too, a trend likely to increase with the urban transition. It should also be noted that the impact of HAP from the use of domestic fuels goes beyond the health of individuals and affects the household economy as well as the local and global environment. Therefore, in order to achieve the SDGs, there is an urgent need to ensure the universal use of CCF.

Funding

Availability of data and materials

The data can be downloaded from the website of the Demographic and Health Survey (DHS) (https://dhsprogram.com/Data/).

Ethical considerations

Our study base on secondary dataset, is available in public domain for research use. Hence, no ethical approval was required from any institutional review board.

Consent for publication

Not applicable.

CRediT authorship contribution statement

Samarul Islam: Conceptualization, Methodology, Software, Data curation, Writing - original draft, Visualization, Investigation, Reviewing and Editing. **Sanjay K Mohanty:** Supervision, Methodology, Visualization, Validation, Reviewing and Editing, All the authors read and approved the final manuscript.

Declaration of competing interest

The authors declare that they have no competing interests.

References

Amegah, A. K., Quansah, R., & Jaakkola, J. J. (2014). Household air pollution from solid fuel use and risk of adverse pregnancy outcomes: A systematic review and meta-analysis of the empirical evidence. *PloS One, 9*(12), Article e113920.

Aryastami, N. K., Shankar, A., Kusumawardani, N., Besral, B., Jahari, A. B., & Achadi, E. (2017). Low birth weight was the most dominant predictor associated with stunting among children aged 12–23 months in Indonesia. *BMC Nutrition, 3*(1), 16.

Balakrishnan, K., Ghosh, S., Ganguli, B., Sambandam, S., Bruce, N., Barnes, D. F., & Smith, K. R. (2013). State and national household concentrations of PM 2.5 from solid cookfuel use: Results from measurements and modeling in India for estimation of the global burden of disease. *Environmental Health, 12*(1), 77.

Balakrishnan, K., Ghosh, S., Thangavel, G., Sambandam, S., Mukhopadhyay, K., Puttaswamy, N., … Natesan, D. (2018). Exposures to fine particulate matter (PM2. 5) and birthweight in a rural-urban, mother-child cohort in Tamil Nadu, India. *Environmental Research, 161*, 524–531.

Balakrishnan, K., Ramaswamy, P., Sambandam, S., Thangavel, G., Ghosh, S., Johnson, P., … Thanasekaraan, V. (2011). Air pollution from household solid fuel combustion in India: An overview of exposure and health related information to inform health research priorities. *Global Health Action, 4*(1), 5638.

Balakrishnan, K., Sambandam, S., Ramaswamy, P., Mehta, S., & Smith, K. R. (2004). Exposure assessment for respirable particulates associated with household fuel use in rural districts of Andhra Pradesh, India. *Journal of Exposure Science and Environmental Epidemiology, 14*(1), S14–S25.

Barnes, D., & Sen, M. (2004). *The impact of energy on women's lives in rural India.* UNDP/ ESMAP.

Bartington, S. E., Bakolis, I., Devakumar, D., Kurmi, O. P., Gulliver, J., Chaube, G., … Hansell, A. L. (2017). Patterns of domestic exposure to carbon monoxide and particulate matter in households using biomass fuel in Janakpur, Nepal. *Environmental pollution, 220*, 38–45.

Belbasis, L., Savvidou, M. D., Kanu, C., Evangelou, E., & Tzoulaki, I. (2016). Birth weight in relation to health and disease in later life: An umbrella review of systematic reviews and meta-analyses. *BMC Medicine, 14*(1), 147.

Bernstein, I. M., Horbar, J. D., Badger, G. J., Ohlsson, A., Golan, A., & Vermont Oxford Network. (2000). Morbidity and mortality among very-low-birth-weight neonates with intrauterine growth restriction. *American Journal of Obstetrics and Gynecology, 182*(1), 198–206.

Bhargava, A., Khanna, R. N., Bhargava, S. K., & Kumar, S. (2004). Exposure risk to carcinogenic PAHs in indoor-air during biomass combustion whilst cooking in rural India. *Atmospheric Environment, 38*(28), 4761–4767.

Boy, E., Bruce, N., & Delgado, H. (2002). Birth weight and exposure to kitchen wood smoke during pregnancy in rural Guatemala. *Environmental Health Perspectives, 110* (1), 109–114.

Brooks, A. M., Byrd, R. S., Weitzman, M., Auinger, P., & McBride, J. T. (2001). Impact of low birth weight on early childhood asthma in the United States. *Archives of Pediatrics & Adolescent Medicine, 155*(3), 401–406.

Clark, M. L., Reynolds, S. J., Burch, J. B., Conway, S., Bachand, A. M., & Peel, J. L. (2010). Indoor air pollution, cookstove quality, and housing characteristics in two Honduran communities. *Environmental Research, 110*(1), 12–18.

Chowdhury, S, Chafe, Z, A, Pillarisetti, A, Lelieveld, J, Guttikunda, S, & Dey, S (2019). *The contribution of household fuels to ambient air pollution in India: A comparison of recent estimates.* In Andrew P Grieshop (Ed.). Edited by Santosh Harish and Kirk R. Smith.

Curhan, G. C., Willett, W. C., Rimm, E. B., Spiegelman, D., Ascherio, A. L., & Stampfer, M. J. (1996). Birth weight and adult hypertension, diabetes mellitus, and obesity in US men. *Circulation, 94*(12), 3246–3250.

Du, B., Tandoc, M. C., Mack, M. L., & Siegel, J. A. (2020). Indoor CO2 concentrations and cognitive function: A critical review. *Indoor Air, 30*(6), 1067–1082.

Epstein, M. B., Bates, M. N., Arora, N. K., Balakrishnan, K., Jack, D. W., & Smith, K. R. (2013). Household fuels, low birth weight, and neonatal death in India: The separate impacts of biomass, kerosene, and coal. *International Journal of Hygiene and Environmental Health, 216*(5), 523–532.

ESMAP. (2020). *The state of access to modern energy cooking services (English).* Washington, D.C.: World Bank Group.

Fullerton, D. G., Bruce, N., & Gordon, S. B. (2008). Indoor air pollution from biomass fuel smoke is a major health concern in the developing world. *Transactions of the Royal Society of Tropical Medicine and Hygiene, 102*(9), 843–851.

Gakidou, E., Afshin, A., Abajobir, A. A., Abate, K. H., Abbafati, C., Abbas, K. M., … Abu-Raddad, L. J. (2017). Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of

risks, 1990–2016: A systematic analysis for the global burden of disease study 2016. *The Lancet, 390*(10100), 1345–1422.

Ha, S. U., Thompson, L. A., Kearney, G., Roth, J., & Xu, X. (2014). Population attributable risks of neurobehavioral disorders due to low birth weight in US children. *Advances Pediatric Research, 1*.

Health Effects Institute. (2020). *State of global air 2020. Special report*. Boston, MA: Health Effects Institute.

Héroux, M. E., Clark, N., Ryswyk, K. V., Mallick, R., Gilbert, N. L., Harrison, I., … MacNeill, M. (2010). Predictors of indoor air concentrations in smoking and non-smoking residences. *International Journal of Environmental Research and Public Health, 7*(8), 3080–3099.

Horbar, J. D., Badger, G. J., Carpenter, J. H., Fanaroff, A. A., Kilpatrick, S., LaCorte, M., … Soll, R. F. (2002). Trends in mortality and morbidity for very low birth weight infants, 1991–1999. *Pediatrics, 110*(1), 143–151.

Huang, T., Wang, T., Zheng, Y., Ellervik, C., Li, X., Gao, M., … Noordam, R. (2019). Association of birth weight with type 2 diabetes and glycemic traits: A mendelian randomization study. *JAMA network open, 2*(9). e1910915-e1910915.

IIPS and ICF. (2017). *National family health survey (NFHS-4)*. IIPS. India." (2017).

Islam, S., Rana, M. J., & Mohanty, S. K. (2020). Cooking, smoking, and stunting: Effects of household air pollution sources on childhood growth in India. *Indoor Air*, 1–21. https://doi.org/10.1111/ina.12730

Jiang, R., & Bell, M. L. (2008). A comparison of particulate matter from biomass-burning rural and non-biomass-burning urban households in northeastern China. *Environmental Health Perspectives, 116*(7), 907–914.

Jiang, M., Qiu, J., Zhou, M., He, X., Cui, H., Lerro, C., … Xu, R. (2015). Exposure to cooking fuels and birth weight in lanzhou, China: A birth cohort study. *BMC Public Health, 15*(1), 712.

Johnson, R. C., & Schoeni, R. F. (2011). The influence of early-life events on human capital, health status, and labor market outcomes over the life course. *The B.E. Journal of Economic Analysis & Policy, 11*(3).

Junaid, M., Syed, J. H., Abbasi, N. A., Hashmi, M. Z., Malik, R. N., & Pei, D. S. (2018). Status of indoor air pollution (IAP) through particulate matter (PM) emissions and associated health concerns in South Asia. *Chemosphere, 191*, 651–663.

Kar, A., Pachauri, S., Bailis, R., & Zerriffi, H. (2019). Using sales data to assess cooking gas adoption and the impact of India's Ujjwala programme in rural Karnataka. *Nature Energy, 4*(9), 806–814.

Khandelwal, M., Hill, M. E., Jr., Greenough, P., Anthony, J., Quill, M., Linderman, M., & Udaykumar, H. S. (2017). Why have improved cook-stove initiatives in India failed? *World Development, 92*, 13–27.

Khan, M. N., Islam, M. M., Islam, M. R., & Rahman, M. M. (2017). Household air pollution from cooking and risk of adverse health and birth outcomes in Bangladesh: A nationwide population-based study. *Environmental Health, 16*(1), 57.

Kim, K. H., Jahan, S. A., & Kabir, E. (2011). A review of diseases associated with household air pollution due to the use of biomass fuels. *Journal of Hazardous Materials, 192*(2), 425–431.

Klepeis, N. E., Nelson, W. C., Ott, W. R., Robinson, J. P., Tsang, A. M., Switzer, P., … Engelmann, W. H. (2001). The national human activity pattern survey (NHAPS): A resource for assessing exposure to environmental pollutants. *Journal of Exposure Science and Environmental Epidemiology, 11*(3), 231–252.

Manjula, M., & Gopi, G. (2017). Universal access to clean cooking energy and the need for an inclusive policy: Evidence from analysis of cooking fuel use in odisha and Tamil Nadu. *Decision, 44*(3), 193–207.

Martin, W. J., Hollingsworth, J. W., & Ramanathan, V. (2014). Household air pollution from cookstoves: Impacts on health and climate. In *Global climate change and public health* (pp. 237–255). New York, NY: Humana Press.

Milanzi, E. B., & Namacha, N. M. (2017). Maternal biomass smoke exposure and birth weight in Malawi: Analysis of data from the 2010 Malawi Demographic and Health Survey. *Malawi Medical Journal, 29*(2), 160–165.

Ministry of Health and Family Welfare. (2013). *Framework for implementation*. National Health Mission, 2012–2017.

Mishra, V., Dai, X., Smith, K. R., & Mika, L. (2004). Maternal exposure to biomass smoke and reduced birth weight in Zimbabwe. *Annals of Epidemiology, 14*(10), 740–747.

Mukhopadhyay, R., Sambandam, S., Pillarisetti, A., Jack, D., Mukhopadhyay, K., Balakrishnan, K., … Smith, K. (2012). Cooking practices, air quality, and the acceptability of advanced cookstoves in Haryana, India: An exploratory study to inform large-scale interventions. *Global Health Action, 5*(1), 19016.

National, R. H. M. (2005). National rural health mission (2005-2012) –Mission document. *Indian Journal of Public Health, 49*(3), 175.

Naz, S., Page, A., & Agho, K. E. (2017). Household air pollution from use of cooking fuel and under-five mortality: The role of breastfeeding status and kitchen location in Pakistan. *PloS One, 12*(3), Article e0173256.

Pandey, A, Brauer, M, Cropper, M, L, Balakrishnan, K, Mathur, P, Dey, S, et al. (2020). Health and economic impact of air pollution in the states of India: the Global Burden of Disease Study 2019. *The Lancet Planetary Health*. https://doi.org/10.1016/S2542-5196(20)30298-9

Pope, D. P., Mishra, V., Thompson, L., Siddiqui, A. R., Rehfuess, E. A., Weber, M., & Bruce, N. G. (2010). Risk of low birth weight and stillbirth associated with indoor air pollution from solid fuel use in developing countries. *Epidemiologic Reviews, 32*(1), 70–81.

PIB. (2016). *Pradhan Mantri Ujjwala Yojana A giant step towards better life for all*. Press Information Bureau. http://pib.nic.in/newsite/printrelease.aspx?relid=148971 Accessed 11 Mar. 20.

Rahman, M. S., Howlader, T., Masud, M. S., & Rahman, M. L. (2016). Association of low-birth weight with malnutrition in children under five years in Bangladesh: Do mother's education, socio-economic status, and birth interval matter? *PloS One, 11*(6), Article e0157814.

Rosenthal, J., Quinn, A., Grieshop, A. P., Pillarisetti, A., & Glass, R. I. (2018). Clean cooking and the SDGs: Integrated analytical approaches to guide energy interventions for health and environment goals. *Energy for Sustainable Development, 42*, 152–159.

Rupakheti, D., Oanh, N. T. K., Rupakheti, M., Sharma, R. K., Panday, A. K., Puppala, S. P., & Lawrence, M. G. (2019). Indoor levels of black carbon and particulate matters in relation to cooking activities using different cook stove-fuels in rural Nepal. *Energy for Sustainable Development, 48*, 25–33.

Sankhyayan, P., & Dasgupta, S. (2019). 'Availability'and/or 'Affordability': What matters in household energy access in India? *Energy Policy, 131*, 131–143.

Siddiqui, A. R., Gold, E. B., Yang, X., Lee, K., Brown, K. H., & Bhutta, Z. A. (2008). Prenatal exposure to wood fuel smoke and low birth weight. *Environmental Health Perspectives, 116*(4), 543.

Smith, K. R., & Pillarisetti, A. (2017). *Household air pollution from solid cookfuels and its effects on health*.

Sreeramareddy, C. T., Shidhaye, R. R., & Sathiakumar, N. (2011). Association between biomass fuel use and maternal report of child size at birth-an analysis of 2005-06 India Demographic Health Survey data. *BMC Public Health, 11*(1), 403.

Talmi, Z., Mankuta, D., & Raz, R. (2020). Birth weight and autism spectrum disorder: A population-based nested case–control study. *Autism Research, 13*(4), 655–665.

Thompson, L. M., Bruce, N., Eskenazi, B., Diaz, A., Pope, D., & Smith, K. R. (2011). Impact of reduced maternal exposures to wood smoke from an introduced chimney stove on newborn birth weight in rural Guatemala. *Environmental Health Perspectives, 119*(10), 1489–1494.

Tielsch, J. M., Katz, J., Thulasiraj, R. D., Coles, C. L., Sheeladevi, S., Yanik, E. L., & Rahmathullah, L. (2009). Exposure to indoor biomass fuel and tobacco smoke and risk of adverse reproductive outcomes, mortality, respiratory morbidity and growth among newborn infants in south India. *International Journal of Epidemiology, 38*(5), 1351–1363.

Torres-Duque, C., Maldonado, D., Pérez-Padilla, R., Ezzati, M., & Viegi, G. (2008). Biomass fuels and respiratory diseases: A review of the evidence. *Proceedings of the American Thoracic Society, 5*(5), 577–590.

UN. (2016). *Transforming our world: The 2030 agenda for sustainable development*. United Nations. https://wedocs.unep.org/bitstream/handle/20.500.11822/11125/unep_swio_sm1_inf7_sdg.pdf?sequence=1. (Accessed 13 January 2021).

World Health Organization. (2014). *WHA global nutrition targets 2025: Stunting policy brief* (pp. 1–6). Geneva https://www.who.int/nutrition/publications/globaltargets2025_policybrief_stunting/en/.

World Health Organization. (2019). *UNICEF-WHO low birthweight estimates: Levels and trends 2000-2015*. World Health Organization. No. WHO/NMH/NHD/19.21.

Wylie, B. J., Coull, B. A., Hamer, D. H., Singh, M. P., Jack, D., Yeboah-Antwi, K., … MacLeod, W. B. (2014). Impact of biomass fuels on pregnancy outcomes in central East India. *Environmental Health, 13*(1), 1.

Yucra, S., Tapia, V., Steenland, K., Naeher, L. P., & Gonzales, G. F. (2014). Maternal exposure to biomass smoke and carbon monoxide in relation to adverse pregnancy outcome in two high altitude cities of Peru. *Environmental Research, 130*, 29–33.