BIOMASS FUEL SMOKE AND STUNTING IN EARLY CHILDHOOD: FINDING FROM A NATIONAL SURVEY NEPAL

Omid Dadras*, Robert S. Chapman

College of Public Health Sciences, Chulalongkorn University, Bangkok, 10330, Thailand

ABSTRACT:

Background: Children who are living in household using biomass fuel for cooking, exposed to high concentration of air pollution. This study examined the potential association of biomass fuel smoke with stunting among children under age 5 in Nepal.

Methods: A cross sectional study, analyzing the secondary data from 2011 Nepal Demographic Health Survey, was conducted. Child stunting was ascertained by measuring the height for age of children under age 5. Biomass fuel smoke exposure determined indirectly by the type of fuel household using for cooking. Bivariate and logistic regression analysis were conducted to estimate the association between biofuel smoke and children stunting, considering the effects of potential confounders.

Results: Children with exposure to biomass fuel smoke showed considerably higher prevalence of stunting (84.6%) compared to children with no exposure (84.6% compared to 15.4%, *p*-value=0.0001). It remained significant even after controlling for potential confounding such as child, mother, environment and geodemographic factors (OR =1.50, 95% CI: 1.04-2.18). In addition, mother's tobacco smoking appeared to be significant prognostic factor for child's stunting after controlling with child and mother factors (OR=1.58, 95% CI: 1.06-2.35).

Conclusion: The findings suggest that there is strong positive association between exposure to biomass fuel smoke and children under age 5 stunting, further prospective epidemiological studies are recommended.

Keywords: Biomass fuel; Children stunting; Biofuel; Indoor air pollution; Cooking smoke

DOI: 10.14456/jhr.2017.62 *Received: March 2017; Accepted: June 2017*

INTRODUCTION

In developing countries, a majority of households are still using biomass fuels (wood, crop residues, dung) as their primary source of energy for cooking, heating and lighting [1]. Biofuels are at the lower end of the energy ladder in term of cleanness and efficient combustion and produce high concentration of air pollution [2]. In addition, using unvented cook stoves with poor ventilation inside the house produce a large amount of Indoor Air Pollution (IAP) which consists of air pollutants such as carbon monoxide (CO), nitrogen oxides, formaldehyde, benzene and many other toxic organic compounds [2, 3]. The health effects of a pollutant are determined not just by its level but most importantly by the exposure duration. The pattern of activity is also important as the exposure time and level could be different when individuals stay indoors or near to the source of pollutant. In developing countries such as Nepal, people are usually exposed to high level of indoor air pollution for 3-7 hours a day over many years [4]. This exposure could happen almost for whole a day during the cold season in mountain area [5]. The exposure level is higher in women as they are accountable for household cooking [6] and most importantly in children as they stay close to the

* *Correspondence to: Omid Dadras*
E-mail: omiddadras@yahoo.com

Cite this article as: Dadras O, Chapman RS. Biomass fuel smoke and stunting in early childhood: finding from a national survey Nepal. J Health Res. 2017; 31(Suppl.1): S7-15. DOI: 10.14456/jhr.2017.62

source of fire while their mother carries them on their back, it could be particularly massive when children are playing around cooking place [7]. Moreover, children are more vulnerable to the air pollution harmful effects and it could result in a number of development problems especially during early childhood [8]. A number of studies have suggested the association between biofuel's smoke with many adverse health effects in childhood such as low birth weight [9, 10], Acute Respiratory Infection (ARI) [11, 12], and death [13]. However, the knowledge on the nutritional status of child is still limited. In developing countries, malnutrition has been mainly attributed to the poverty and underprivileged social status and consequently biomedical disturbance leading to growth retardation. Stunting is the low height for the child age and is result of interaction between various socioeconomic and environmental factors. A limited number of studies examined the association between the biomass fuel smoke and stunting. A study by Mishra and Retherford [14] shown that there is a positive association between biofuel smoke and stunting in children (0–35 months) using the data from a national family health survey in India. The prevalence of severe stunting was remained high even after adjusting for other factors including environmental tobacco smoke. In contrary in another study in Swaziland, the researchers did not identify any significant association [15].

According to the Nepal Demographic Health Survey (NDHS) 2011, approximately 41% of children under age 5 were stunted. In addition, an estimated 74% of Nepal population are still using the biomass fuels as their primary source of energy [16]. Therefore, Nepal is a suitable setting to explore the potential association between biofuel smoke and stunting. In this study, we used the data from NDHS 2011 to examine this relationship, controlling for different potential factors that affect the stunting among children under age 5.

METHODS

This study analyzed the data for children aged 5 years old or less in Nepal Demographic Health Survey (NDHS) conducted in 2011. The purpose of NDHS was to provide current and reliable demographic, socioeconomic, and health data for a nationally representative sample of 10,826 households, 12,674 women and 4121 men aged 15–49, representing all 13 eco-development regions in Nepal. The data for children under age 5 were collected by interviewing mother of respective child.

A stratified, two-stage cluster sampling strategy was employed in NDHS. Overall response rates were 98% for women and 95% for men. The first stage of sampling 289 Enumeration Are (EA) were selected using a Probability Proportional to Size (PPS) strategy. In the second stage, 35 households in each urban EA and 40 households in each rural EA were randomly selected using household's map in selected EA. Sampling weight were calculated, taking into account non-proportional allocation for domain and non-response rate in order to ensure sample representativeness at the national level.

Three standard survey questionnaires were administered in NDHS including the household questionnaire, the women's questionnaire and the Man's Questionnaire and they were carefully translated into the three main local languages -Nepali, Maithali, and Bhojpuri- and back translated and were field pretested, ensuring that they are clear and measuring what they intended to measure. The field staff training took place in Kathmandu from 15 December 2010 to 16 January 2011 for 5 weeks to ensure effective and reliable data collection and management. Data were collected during 23 January to 14 June 2011. Further details about the sampling design, survey management, and quality control are provided in the final survey report [16].

The data on nutritional status of children under age 5 was collected, measuring the height and weight of child in the selected households by field trained staff, using the standard measure and scales. The data allow the calculation of height for age. The total number of children under 5 years old was 5306, however we were just able to analyze the data for 2262 children, whose valid data was available on age (month) and height (cm). Stunting reflects the chronic malnutrition and was defined as height-for-age Z-score below minus two standard deviations (-2 SD) from the median of the WHO reference population. The prevalence of stunted children was our variable of interest in this study.

Exposure to cooking smoke was determined indirectly by type of fuel used for cooking. The survey classified the main cooking fuel to 12 categories including: wood, dung, straw, agricultural crop, charcoal, coal, kerosene, electricity, liquid petroleum gas (LPG), natural gas, biogas, and a residual category of other fuels. The question was, 'What type of fuel does your household mainly use for cooking?' Information on fuel types was used to group households into two categories implying

indirectly the amount of exposure to the smoke including high pollution fuels reflecting the biomass fuels (wood, dung, straw or agricultural crop) and low pollution fuels reflecting relatively clean fuels (LPG, natural gas, biogas, electricity, kerosene, coal or charcoal define the clean fuel) [17]. The small residual category of other fuels (0.05% of the sample) was excluded from the analysis due to unknown nature of fuels in that category.

A number of potential covariates were identified based on previous literature which further used to construct the regression models. The covariates were organized in four categories including child's factors consist of child age (0–5, 6–11, 12–23, 24–35, 36–59), child birth order (1, 2, 3, 4+), child birth size (small, medium, large), child gender, child birth interval (<24moths, >24months). Mother's factors consist of mother age at birth (14-25, 26-35, 36-47), mother education (no education, primary and secondary or higher), mother BMI (underweight, normal weight, overweight, obese), mother anemia (yes, no), mother smoking (yes, no), mother working (yes, no). Environmental factors consist of improved water (yes, no), improved sanitation (yes, no), environmental smoke (no smoke, daily smoke, weekly or more smoke), household member number (≤4, 5-7, ≥8), food security (food secure, mildly/moderately/severely food insecure), wealth index (poor, middle, rich) and last but not least, geodemographic factors consist of living location (urban, rural), religion (Indo, Buddhist, Muslim, Kirat, Christian), ethnicity (Brahmin, Chhetri, Dalit, Janajati, Muslim, others).

STATISTICAL ANALYSIS

All the analysis was carried out using STATA v14, take into account the sampling strategy and sampling weight to ensure the representativeness of results at the national level. Bivariate analysis employed to describe the distribution of child, mother, environmental and geodemographic factors and estimate the stunting prevalence among children under age 5 (Table 1). A number of binary logistic regression models were constructed to estimate the effects of cooking fuel type and other factors on stunting. Regression models were built using the significant covariate within bivariate analysis (Pearson chi-square *p*-value <0.05). The design-adjusted Wald test was used to decide which covariate to be retained in selected model as recommended by Heeringa, et al. (2011) for complex sample analysis [18]. First model was built by including the fuel type and cooking place, second model by further including the child related variables. Likewise, third, fourth and fifth models were constructed by adding mother, environmental and geodemographic variables, respectively. Furthermore, the effect of socioeconomic state on the final model examined (Model 6). Results are presented in the form of odds ratios (OR) with 95% CI (Table 2).

ETHICAL CONSIDERATION

The analysis presented in this paper is based on secondary analysis of existing survey data with all identifying information removed. The survey obtained informed consent from each respondent (in this case, mothers of the children included in the analysis) before asking questions. This study protocol was approved by Committee for Research on Human Subjects in Chulalongkorn University (COA No. 082/2016).

RESULTS

Children characteristics

About 85% of children under age 5 were living in households that rely primarily on high pollution fuels (biofuel) for cooking, the remaining 15% belonged to the households with low pollution fuel as the primary fuel. Indoor cooking was the main cooking practice (70%) in included households. The majority of children (about 91%) were living in rural area whereas only about 9% were living in urban area. The proportion of children living in terai region (52.55) was larger than the other two regions (hill 39.52% and mountain 7.93%).

Bivariate analysis

Fourteen percent of children were suffering of stunting in survey sample. The estimated stunting prevalence among children with exposure to biofuel smoke was about twice as high as the children without exposure (43.47% versus 25.82%, *p*-value = 0.0001). Rural children (41.10%) were notably more stunted. Higher birth order and smaller birth size were associated with higher prevalence of stunting (*p*-value = 0.0001). Children of a mother with higher age, lower education, employed (42.72%) and smoker (61.44%) were considerably more likely to be stunted (*p*-value <0.05). Children with underweighted mother had relatively the highest likelihood of being stunted (47.62%), followed by children of normal weight (39.46%), obese (32.38%) and over weight (26.44%). The prevalence of stunting declined significantly as the food availability in household

Table 1 Sample distribution and stunting prevalence among children age under 5 (%), by selected characteristics, Nepal, 2011

Characteristics	Distribution	Prevalence	*p*-value
Nepal		39.81	
Cooking fuel type			
Low pollution fuel	15.4	25.83	0.0001
High pollution fuel[a]	84.6	43.47	
Cooking place			
Indoor	70.05	41.05	0.1666
Outdoor	29.95	36.57	
Location			
Urban	9.336	27.10	0.0001
Rural	90.66	41.10	
Age in months			
0-5	9.35	18.48	0.0001
6-11	10.11	16.15	
12-23	20.26	36.00	
24-35	20.25	50.77	
36-59	40.02	47.16	
Gender			
Male	51.56	40.84	0.3153
Female	48.44	38.74	
Birth order			
1	33.99	34.86	0.0001
2	27.10	35.37	
3	16.83	39.26	
4+	22.08	53.20	
Birth interval			
Less than 24 months	24.28	46.52	0.1383
More than 24months	75.72	41.27	
Birth size[b]			
Large	17.79	31.25	0.0001
Medium	66.28	39.36	
Small	15.93	50.26	
Mother age at birth			
14-25	55.48	37,80	0.0304
26-35	38.41	41,10	
36-47	6.11	50.4	
Mother's education			
No education	47.29	46.55	0.0001
Primary	20.02	40.57	
Secondary or higher	32.69	29.57	
Mother's working			
No	45.08	36.04	0.0219
Yes	54.92	42.72	
Mother's smoking			
No	92.41	37.89	0.0001
Yes	7.59	61.44	
Mother's BMI			
Underweight	19.38	47.62	0.0001
Normal weight	70.45	39.46	
Overweight	8.827	26.44	
Obese	1.342	32.38	
Mother's anemia			
Not anemic	62.07	39.74	0.7057
Anemic	37.93	40.67	
Environmental smoke			
No smoke	39.87	36.85	0.1154
Daily smoke	44.31	43.10	
Weekly or more smoke	15.82	36.93	
Food security			
Food secure	40.98	32.36	0.0002
Mildly food insecure	12.21	39.05	
Moderately food insecure	25.4	44.87	

Table 1 Sample distribution and stunting prevalence among children age under 5 (%), by selected characteristics, Nepal, 2011 (cont.)

Characteristics	Distribution	Prevalence	*p*-value
Food security			
Severely food insecure	21.42	49.90	
Wealth index			
Poor	47.71	50.39	0.0001
Middle	21.02	34.93	
Rich	31.27	27.76	
Improved sanitation			
Yes	43.2	34.67	0.0005
No	56.8	45.31	
Improved water			
Yes	86.43	39.14	0.0025
No	13.57	50.00	
Household member number			
≤4	28.23	37.54	0.5578
5-7	48.19	40.87	
8≤	23.58	40.37	
Religion			
Indu	82.83	40.89	0.0565
Buddhist	8.212	35.37	
Muslim	6.479	34.16	
Kirat	1.296	46.53	
Christian	1.183	19.04	
Ethnicity			
Brahmin	10.75	29.43	0.0335
Chhetri	19.33	41.89	
Others	13.01	41.47	
Dalit	17.83	44.77	
Janajati	32.55	39.90	
Muslim	6.53	34.16	
Region			
Mountain	7.93	51.20	0.0061
Hill	39.52	41.52	
Terai	52.55	36.84	
No. of children	5306[c]	2262[d]	

[a] Indicate the biomass fuels including wood, animal dung and agriculture residuals

[b] Birth size at the time of birth as reported by mother

[c] Number of children varies slightly depending on the number of missing cases at each variable

[d] Almost half of the data for children stunting missed was due to lack of the data on age (in months)

Table 2 Odds ratio estimates of effects of cooking fuel type and other factors on stunting prevalence among children under age 5, Nepal, 2011

Characteristics	Model1 OR (CI 95%)	Model2 OR (CI 95%)	Model3 OR (CI 95%)	Model 4 OR (CI 95%)	Model5 OR (CI 95%)	Model 6 OR (CI 95%)
Cooking fuel type						
Low pollution fuel	_	_	_	_	_	_
High pollution fuel	2.37(1.73-3.23)	2.11(1.50-2.97)	1.70(1.18-2.46)	1.55(1.07-2.26)	1.50(1.04-2.18)	1.13(0.72-1.76)
Cooking place						
Indoor	_	_	_	_	_	_
Outdoor	0.75(0.58-0.97)	079(0.60-1.03)	0.81(0.62-1.07)	0.85(0.64-1.13)	0.89(0.66-1.19)	0.97(0.73-1.29)
Age in months						
0-5		_	_	_	_	_
6-11		0.94(0.49-1.79)	0.93(0.49-1.78)	0.90(0.47-1.74)	0.86(0.45-1.67)	0.87(0.46-1.67)
12-23		2.77(1.72-4.46)	2.69(1.66-4.35)	2.71(1.67-4.38)	2.68(1.66-4.34)	2.79(1.74-4.48)

Table 2 Odds ratio estimates of effects of cooking fuel type and other factors on stunting prevalence among children under age 5, Nepal, 2011 (cont.)

Characteristics	Model1 OR (CI 95%)	Model2 OR (CI 95%)	Model3 OR (CI 95%)	Model 4 OR (CI 95%)	Model5 OR (CI 95%)	Model 6 OR (CI 95%)
Age in months						
24-35		4.65(2.91-7.42)	4.53(2.83-7.25)	4.55(2.85-7.27)	4.55(2.86-7.24)	4.70(2.97-7.41)
36-59		4.11(2.54-6.63)	4.03(2.47-6.58)	4.11(2.52-6.68)	4.11(2.52-6.71)	4.22(2.61-6.83)
Birth size						
Large		_	_	_	_	_
Medium		1.51(1.15-1.98)	1.46(1.11-1.92)	1.49(1.13-1.97)	1.48(1.12-1.97)	1.49(1.14-1.95)
Small		2.26(1.59-3.22)	2.11(1.47-3.02)	2.14(1.50-3.07)	2.18(1.52-3.12)	2.14(1.51-3.05)
Birth order						
1		_	_	_	_	_
2		1.07(0.81-1.41)	1.02(0.76-1.37)	1.01(0.75-1.36)	1.01(0.74-1.36)	1.00(0.74-1.36)
3		1.11(0.79-1.58)	1.00(0.68-1.46)	1.01(0.69-1.49)	1.01(0.66-1.48)	1.00(0.68-1.46)
4+		1.95(1.48-2.56)	1.64(1.18-2.28)	1.59(1.13-2.25)	1.57(1.12-2.21)	1.56(1.10-2.20)
Mother's BMI						
Underweight			_	_	_	_
Normal weight			0.79(0.59-1.05)	0.78(0.58-1.05)	0.76(0.56-1.03)	0.76(0.55-1.04)
Overweight			0.60(0.38-0.93)	0.62(0.39-0.97)	0.59(0.37-0.93)	0.63(0.39-1.01)
Obese			0.69(0.32-1.48)	0.73(0.34-1.60)	0.76(0.34-1.69)	0.69(0.31-1.51)
Mother's smoking						
No			_	_	_	_
Yes			1.58(1.06-2.35)	1.46(0.99-2.15)	1.36(0.92-1.99)	1.32(0.90-1.94)
Mother's education						
No education			_	_	_	_
Primary			1.01(0.71-1.43)	01.06(.74-1.50)	1.07(0.75-1.53)	1.13(0.79-1.60)
Secondary or above			0.80(0.56-1.14)	0.86(0.60-1.25)	0.88(060-1.31)	1.03(0.69-1.54)
Improved water						
Yes				_	_	
No				1.28(0.93-1.78)	1.24(0.88-1.73)	1.16(0.83-1.63)
Food security						
Food secure				_	_	
Mildly food insecure				0.97(0.67-1.40)	0.95(0.66-1.38)	0.89(0.61-1.30)
Moderately food insecure				1.33(0.96-1.84)	1.33(0.96-1.85)	1.21(0.86-1.69)
Severely food insecure				1.41(0.97-2.07)	1.46(0.99-2.15)	1.25(0.85-1.86)
Region						
Hill					_	
Mountain					1.41(1.02-1.97)	1.39(1.00-1.93)
Terai					0.86(0.63-1.17)	1.00(0.72-1.40)
Ethnicity						
Others					_	
Brahmin					0.68(0.41-1.13)	0.67(0.41-1.09)
Chhetri					0.76(0.51-1.13)	0.72(0.48-1.08)
Dalit					0.78(0.51-1.18)	0.73(0.47-1.12)
Janajati					0.75(0.51-1.12)	0.69(0.45-1.04)
Muslim					0.70(0.38-1.30)	0.66(0.36-1.21)
Wealth index						
Poor						
Middle						0.68(0.47-0.99)
Rich						0.51(0.31-0.85)
Number of children	2,262	2,260	2,260	2,260	2,254	2254

became more secured (Table 2). Likewise, in rich households which have higher food security the proportion of stunted children (27.76%) was considerably lower than poor households with less food security (50.39%). The distribution of child's stunting prevalence was significantly different between ethnic groups, with highest in Dalit ethnic (44.77%) and lowest in Brahmin ethnic (29.43%)

children. Children who reside in mountain zone (51.2%) were considerably more suffering from stunting (*p*-value=0.0001).

Logistic regression

In binary regression analysis, the adjusted odd ratio for stunting in children under age 5 was almost two times higher in the biofuel smoke exposure than low pollution exposure (OR=2.37, 95% CI: 1.73-3.23) after adjusting for cooking place (Table 2, Model 1). The effect of biofuel smoke on child stunting remained large and statistically significant when child age, birth size and order were controlled in the Model 2 (OR =2.11, 95% CI: 1.50-2.97). Although the adjusted odds ratio for the type of fuel effect remain statistically significant, it reduced slightly after controlling for mother (Table 2, Model 3, OR =1.70, 95% CI: 1.18-2.46), environmental (Table 2, Model 4, OR =1.55, 95% CI: 1.07-2.26) and geodemographic (Table 2, Model 5, OR =1.50, 95% CI: 1.04-2.18) variables. It is suggesting the immense effect of biomass fuel smoke on child stunting regardless of other factors. However, it became insignificant in the sixth model (OR =1.13, 95% CI: 0.72-1.76) after further adjusting for household wealth index. Since the wealth index is an indicator of the household socioeconomic status, this phenomenon could suggest that socioeconomic status may upstream determine the type of fuel used in household for cooking. It also appeared to be a potential prognostic factor for the stunting and some other variables within the model such as food security which also become insignificant (Model 6, Table 2). By controlling the type of fuel and other variables in final model (Model 5), the child age, birth order and size, region of residence and food security were the only variables that largely affected the child stunting (Table 2). Similar to significant difference in prevalence of stunting in bivariate analysis (Table 1), children in 24-35months age group, being in >4 in birth order and small reported birth size who resided in mountain region and belonged to a severely food insecure household has a larger and statistically significant adjusted odds ratios (Model 5, Table 2).

DISCUSSION

In many developing countries, households still continue to use biomass fuels as their primary source of energy, particularly for cooking. biofuels smoke poses immense health risk on mother and young children in developing countries [19]. In Nepal, about two third of households rely on biofuels, mainly wood, in their daily cooking practice. In Nepal, about 40 % of children under age 5 are stunted, 11% are wasted, and 29 % are underweight. It places the malnutrition as one the leading causes of child morbidity and mortality in this country [16]. Our study showed that there is a strong positive association between the biofuel smoke (high pollution fuel exposure) and stunting among children under age 5. It remains significant even after controlling for child's age, birth order and birth size, mother BMI, education and smoking, and other environmental and geodemographic covariates, this finding was consistent with Mishra and Retherford's study in India [20], however, in contrast to their study, the effect of mother's tobacco smoking, adjusted for child and mother covariates, showed to be significantly associated with child's stunting. Even though an array of studies suggested that father's tobacco smoking increased the risk of child stunting [21, 22], the evidence for the effect of mother smoking on stunting are limited. The prevalence of tobacco smoking among women is not as high as men. Nonetheless, since mother smoking particularly pose a greater risk on child health, further prospective epidemiological studies, focused on maternal smoking, would be valuable. In this study, we also indicated that household economic status could nullify the strong association between the biofuel smoke and child stunting. The results indicate, the richer the family, the less stunting prevalence. This points to the poverty, once again, as possibly the foremost cause of malnutrition [23]. Despite the extensive efforts for providing the rural area in the country with electricity in the country, still approximately 75% of households continue to use biofuels as a source of energy for cooking due to its affordable price [16, 24]. It would inform and advise the interventions and policies in Nepal to direct their efforts more efficiently, targeting the underlying causes of malnutrition.

Several measurement limitations should be considered when applying the findings of this study. The higher mortality due to stunting in underprivileged households using biofuels, could underestimate the strength of biofuel smoke effect. However, relatively low mortality rate and high prevalence of stunting could compensate for such bias in our estimated effect.

Another limitation is the unknown gap in health services access and coverage between different socioeconomic classes and regions in country which indirectly affect the child's health and survival.

Although, to some extent, we compensated for such bias by controlling for related variables such as wealth index or region, there is always a potential effects of some residual confounding.

In DHS survey, stunting is rather precisely measured using standard and reliable scale and procedures but smoke exposure was determined indirectly from type of fuel used for cooking and heating. The studies in Nepal and other developing countries, however, demonstrated that unprocessed solid fuels contribute to a substantial production of pollution per meal compared to electricity, liquid and gaseous fuels [25], but still this inadequate measurement may introduce a bias toward underestimating the effects of biofuel smoke on stunting.

Although the cross sectional design of this study is supposed not to allow any causal inference, the time direction of cause (biofuel smoke) and effect (stunting) along with higher prevalence of stunting among children, living in households with biofuel for cooking may suggest a causal relationship between biofuel smoke and children under age 5 stunting. This causal inference could be downwardly biased if some households shifted from biofuels to cleaner fuels in the recent years prior to the time of the survey. Despite aforementioned limitations, our study was conducted using a large nationally representative sample of children under age 5 with standard anthropometric measurement which strength the validity and reliability of the results.

CONCLUSION

The study observed a high prevalence of stunted children in the Nepali population using biofuel for cooking and provide further evidence that support the existent knowledge. It suggests the "national" policies and interventions to provide cleaner fuels and improved stove with affordable price for households using biomass fuels as their primary source of energy for cooking. However, further research using a prospective epidemiological design, on the relationship between biofuel smoke exposure and stunting is advisable to be capable of reliable and valid causal relationship inference.

REFERENCES

1. Bruce N, Perez-Padilla R, Albalak R. Indoor air pollution in developing countries: a major environmental and public health challenge. Bull World Health Organ. 2000; 78(9): 1078-92.
2. Smith KR, Liu Y. Indoor air pollution in developing countries. In: Samet JM, editor. Epidemiology of lung cancer, lung biology in health and disease. [N.p.], 1994. p.151-84.
3. World Health Organization [WHO]. World Health Report 2002: reducing risks, promoting healthy life. Geneva: WHO; 2001.
4. Engle PL, Hurtado E, Ruel M. Smoke exposure of women and young children in highland guatemala: prediction and recall accuracy. Human Organization. 1997; 56(4): 408-17.
5. Norboo T, Yahya M, Bruce NG, Heady JA, Ball KP. Domestic pollution and respiratory illness in a Himalayan village. Int J Epidemiol. 1991; 20(3): 749-57.
6. Behera D, Dash S, Malik SK. Blood carboxyhaemoglobin levels following acute exposure to smoke of biomass fuel. Indian J Med Res. 1988 Dec; 88: 522-4.
7. Albalak R. Cultural practices and exposure to particles pollution from in door biomass cooking: effects on respiratory health and nutrtitional status among the Aymara Indians of the Bolivia n Highlands. Michigan: University of Michigan; 1997.
8. Tanner JM. Growth as a mirror of the condition of society: secular trends and class distinctions. In: Demirjian A, editor. Human growth: a multidisciplinary review. London–Philadelphia: Taylor and Francis; 1986. p.3-34.
9. Jiang M, Qiu J, Zhou M, He X, Cui H, Lerro C, et al. Exposure to cooking fuels and birth weight in Lanzhou, China: a birth cohort study. BMC Public Health. 2015 Jul; 15(15): 712. doi: 10.1186/s12889-015-2038-1
10. Mishra V, Dai X, Smith KR, Mika L. Maternal exposure to biomass smoke and reduced birth weight in Zimbabwe. Ann Epidemiol. 2004 Nov; 14(10): 740-7. doi: 10.1016/j.annepidem.2004.01.009
11. Misra P, Srivastava R, Krishnan A, Sreenivaas V, Pandav CS. Indoor air pollution-related acute lower respiratory infections and low birthweight: a systematic review. J Trop Pediatr. 2012 Dec; 58(6): 457-66. doi: 10.1093/tropej/fms017
12. Pandey MR, Neupane RP, Gautam A, Shrestha IB. Domestic smoke pollution and acute respiratory infections in a rural community of the hill region of Nepal. Environment International. 1989; 15(1): 337-40. doi: 10.1016/0160-4120(89)90046-9
13. Pope DP, Mishra V, Thompson L, Siddiqui AR, Rehfuess EA, Weber M, et al. Risk of low birth weight and stillbirth associated with indoor air pollution from solid fuel use in developing countries. Epidemiol Rev. 2010; 32: 70-81. doi: 10.1093/epirev/mxq005
14. Mishra V, Retherford RD. Does biofuel smoke contribute to anaemia and stunting in early childhood? Int J Epidemiol. 2007 Feb; 36(1): 117-29. doi: 10.1093/ije/dyl234
15. Machisa M, Wichmann J, Nyasulu PS. Biomass fuel use for household cooking in Swaziland: is there an association with anaemia and stunting in children aged

6-36 months? Trans R Soc Trop Med Hyg. 2013 Sep; 107(9): 535-44. doi: 10.1093/trstmh/trt055

16. USAID. The 2011 Nepal Demographic and Health Survey. Katmandu: USAID; 2011.
17. Mishra V. Indoor air pollution from biomass combustion and acute respiratory illness in preschool age children in Zimbabwe. Int J Epidemiol. 2003 Oct; 32(5): 847-53.
18. Heeringa SG. Applied survey data analysis. 2nd ed. Londod: CRC Press; 2011.
19. Smith KR, Mehta S. The burden of disease from indoor air pollution in developing countries: comparison of estimates. Int J Hyg Environ Health. 2003 Aug; 206(4-5): 279-89. doi: 10.1078/1438-4639-00224
20. Mishra VK, Retherford RD, Smith KR. Biomass cooking fuels and prevalence of blindness in India. Journal of Environmental Medicine. 1999; 1(4): 189-99.
21. Best CM, Sun K, de Pee S, Sari M, Bloem MW, Semba RD. Paternal smoking and increased risk of child malnutrition among families in rural Indonesia. Tob Control. 2008 Feb; 17(1): 38-45. doi: 10.1136/tc.2007.020875
22. Chowdhury F, Chisti MJ, Hossain MI, Malek MA, Salam MA, Faruque AS. Association between paternal smoking and nutritional status of under-five children attending Diarrhoeal Hospital, Dhaka, Bangladesh. Acta Paediatr. 2011 Mar; 100(3): 390-5. doi: 10.1111/j.1651-2227.2010.02067.x
23. Sapkota VP, Gurung CK. Prevalence and Predictors of Underweight, Stunting and Wasting in Under-Five Children. Journal of Nepal Health Research Council. 2009; 7(15).
24. United Nations Development Programme [UNDP]. Rural Energy Development Programme in Nepal 2012. Available from: http://www.undp.org/content/undp/en/home/ourwork/environmentandenergy/projects_and_initiatives/rural-energy-nepal.html
25. Ranabhat CL, Kim CB, Kim CS, Jha N, Deepak KC, Connel FA. Consequence of indoor air pollution in rural area of Nepal: a simplified measurement approach. Front Public Health. 2015; 3: 5. doi: 10.3389/fpubh.2015.00005