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Use of solid fuel and acute respiratory infections among children younger than five years in Bangladesh

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**Research article**

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**Abstract**

**Aim:** Acute respiratory infection (ARI) is the primary cause of death among Bangladeshi children under the age of five. For cooking, low-income families frequently rely on wood, coal, and animal excrement. It is not clear whether the use of other fuel has health advantage over solid fuels. Therefore, we aim to conduct a study to detect the effects of fuel usage on ARI in children. **Materials and Methods:** Using the Bangladesh Demographic & Health Survey (BDHS) 2017-18 data, we estimated the effect of fuel use on ARI by constructing logistic regression models. A multiple logistic regression model was used to assess risk factors of ARI due to fuel use. **Results:** From the analysis, we found the crude (only type of fuel in the model) odds ratios (OR) for the ARI were 1.693 (95% confidence interval (CI): 1.058-2.709). That means children in households using polluting fuels were 69.3% more likely to have an ARI event than children from households using clean fuels. After adjusting for cooking fuel, Type of roof material, child's age (months), and sex of child, indicated that the effect of solid fuels is also more acute as adjusted odds ratio (AOR) for the ARI were 1.692 (95% CI: 1.053-2.718) or 69.2% more likely to have an ARI event compared with the effect of clean fuel. **Conclusion:** Findings of the study have significant association between use of solid fuel and presence of ARI of a child in the household. The link between indoor air pollution and clinical parameters of acute respiratory illness has to be investigated further.

**Keywords:** Solid fuels; Clean fuels; Acute Respiratory Infection (ARI); Under-five children.

**Introduction**

In underdeveloped countries around the world, acute respiratory infection (ARI) is a primary cause of death in children under the age of five. Nowadays it is one of the major causes of permanent damage and communicable disease death [1]. Acute respiratory infection is a serious infection that makes it difficult to breathe normally. Though it's nearly impossible to prove that viruses and bacteria, the main risk factors for developing acute respiratory illness, start in the nose, trachea (windpipe), or lungs, it usually starts in the nose, trachea (windpipe), or lungs. The common viruses that are responsible for ARI are influenza viruses (IFVs), respiratory syncytial virus (RSV), parainfluenza viruses (PIVs) [2]–[4]. Children, the elderly, and persons with immune system abnormalities are especially vulnerable. The serious rise in illness and mortality caused by respiratory viruses have made ARI a top priority in the global health challenge.

The World Health Organization issued a global notice on a common pneumonia called severe acute respiratory syndrome on March 12, 2003 [5]. In 1990 the conditions represented the first cause of disability-adjusted years of life lost among girls and the second in boys under 5 years of age, explaining about 18% of the global burden of disease and producing between 3.5 and 5.0 million deaths [6]. Acute respiratory infections kill an estimated 2.6 million children globally each year, according to the World Health Organization (WHO). Children with respiratory infections account for 20% to 40% of outpatient clinic visits, while hospital admissions account for 12% to 35% of admissions [7]. About 500 to 900 million acute respiratory infection cases occur per year in developing countries. Also, around 5 million of children who are under five die of this infection annually, of which 90% occur in developing countries [8]. The precise magnitude of ARI in Bangladesh is unknown. ARI, which is already at a very large scale, is increasing at the double. The risk of infectious disease epidemics is usually considered to be low, but this may lead to avoid the common conditions such as ARI which is less noticeable than epidemic-prone diseases in Bangladesh. Unlike cholera or acute malnutrition, there are no acceptable benchmarks for ARI, making it difficult to measure case management quality using established criteria. Several studies stated that there are high correlations between environmental risk factors, such as smoke, outdoor air pollution, indoor pollution, passive smoking, overcrowding and risk factors in the child ,such as low birth weight, malnutrition, measles, breast feeding and vitamin ‘A’ deficiency, stunting, wasting, type of cooking fuel, toilet facilities, mothers literacy, medication for intestinal parasite ,place of residence, BMI, wealth index ,media, size of child birth with the infections, are potential risk factors for pneumonia/ARI in developing countries

The burning of cooking fuel is not necessarily the only source of indoor air pollution, although it is considered the major source. Pollutants from dirty fuel sources used for indoor space heating and lighting are among the other sources [16]. Due to limited availability and access to non-solid or clean fuels such as electricity and natural gas, low-income families in many developing countries rely on the use of low-cost but high-pollution solid fuels such as wood, coal, straws, and animal dung as their primary source of energy for cooking and heating, yet 19.0%, 6.8%, and 50.9% of households in Bangladesh used crop, animal dung and wood, respectively, these fuels for cooking, heating and lighting, even when access to electricity was available [17]. Smoke from polluting fuel burning emits a variety of harmful air pollutants, including respirable particulate matter such as PM 2.5 (particulate matter < 2.5 µm in aerodynamic diameter) and PM (< 10 µm in aerodynamic diameter), carbon monoxide (CO), nitrogen oxides (NO), formaldehyde, benzene, polycyclic aromatic hydrocarbons (PAHs) (such as the carcinogen benzo[a]pyrene, B[a]P) and many other toxic volatile organic compounds (VOCs) [18]. In comparison with liquefied petroleum gas (LPG), wood and cow dung produce 19 and 64 times more CO, 17 and 115 times more hydrocarbons, and 26 and 63 times more PM, respectively [19]. The fuels are primarily used in simple, inefficient, and mostly unvented family cooking stoves, resulting in enormous amounts of indoors smoke due to poor ventilation [20]. Exposure to these pollutants in developing countries is reported to be higher in women and children [21].

In Bangladesh, 80% of households use solid fuel for cooking (coal/lignite, charcoal, wood, straw/shrubs/grass, agricultural crops, and animal dung), while 20% use clean fuel (electricity, and liquid petroleum gas/natural gas/biogas) [22]. However, no studies have been undertaken in Bangladesh to investigate the link between ARI in children and solid fuel exposure, to the authors' knowledge. As a result, using the most recent data available, this study looked at the link between solid fuel exposure and ARI in Bangladeshi children under the age of five.

**Materials and Methods**

**Study area**

Bangladesh is one of the world's most densely populated countries, with a delta of rivers empties into the Bay of Bengal [23]. It is a densely populated, low-lying, primarily riverine country in South Asia's tropical monsoon region, with a mean elevation of 85 meters above sea level and a climate marked by high temperatures, heavy rainfall, cyclones, tidal bores, often excessive humidity, and fairly marked seasonal variations [24], [25].

**Data source and Study design**

For this investigation, we used data from the Bangladesh Demographic and Health Survey (BDHS) 2017-18. In the first step, 675 EAs were chosen with a probability proportionate to EA size (250 in urban regions and 425 in rural areas). A systematic sample of 30 households per EA was chosen in the second step of sampling to give statistically credible estimates of key demographic and health characteristics for the country as a whole, for urban and rural areas separately, and for each of the eight divisions. A total of 20,250 residential households were chosen based on this concept. About 20,100 ever-married women aged 15 to 49 were expected to complete the interviews. Mothers of 8347 children younger than 5 years were questioned about, demographic, economic, pregnancy, postnatal care, immunization and health issues, including ARI symptoms. Our final sample for analysis consisted of 8321 (weighted) children after we limited our sample to children for whom complete data on the outcome and predictors considered for the analysis were available. After excluding non-eligible cases (e.g., others fuel type, visitors and non-surviving children) and observations with missing information on the child's age. The sampling procedure is represented in figure 1. The 2017-18 BDHS report includes a detailed discussion of the sample design and technique [22].

**Ethical approval**

Our study was wholly based on an analysis of existing public domain health survey datasets obtained from BDHS 2017-18, which is freely available online with all identifier information removed. Informed consent was obtained from participants while interviewing them. The BDHS 2017-18 was reviewed and approved by the ICF Macro Institutional Review Board and the National Research Ethics Committee of the Bangladesh Medical Research Council. This survey was conducted by the National Institute of Population Research and Training (NIPORT) of the Ministry of Health and Family Welfare and implemented by Mitra and Associates, Bangladesh.

**Outcome variable**

The outcome variable of interest was ARI in children under the age of five. In this survey, ARI is defined as the mother’s or caregiver’s perception of whether their child had a cough accompanied by chest related short, rapid breathing in the 2 weeks before the survey [22]. When respondents said yes, the ARI variable was classified as 1, and when they said no, it was coded as 0.

**Exposure variable**

Solid fuel, which was ascertained by type of fuel used for cooking or heating was the exposure variable of interest in this study. Each household's type of cooking fuel was collected by the BDHS. 'What type of fuel does your home primarily use for cooking?' survey respondents were asked [22]. Fuel types were classified into: coal/lignite, charcoal, wood, straw/shrubs/grass, agricultural crops, animal dung, electricity, and liquid petroleum gas/natural gas/biogas. The exposure variable was a binary variable that indicates types of cooking fuel: clean fuel versus solid fuel. Coal/lignite, charcoal, wood, straw/shrubs/grass, agricultural crops, and animal dung were considered as solid fuels. The use of electricity, and liquid petroleum gas/natural gas/biogas were classified as clean fuel. Fuel type variable is coded as 1 if the household use clean fuel, otherwise 0 (solid fuel).

**Covariates**

By reviewing the valid literature, the most potentially related and assumed variables associated with ARI were included in this study. Household related factors (place of residence, region of the country, media accessibility (possession of television or radio), source of drinking water, toilet facility, wealth index, electricity accessibility, type of flooring material, type of roof material, type of wall material, and number of household member), parents/caregivers related factors (having a health card (vaccination), mother’s age, mother’s education level, mother’s BMI, number of living children, mother’s occupation, mother’s work for, household head’s occupation, household head’s education, and type of household head’s education), and child-related factors (child’s age, sex of child, birth order, place of delivery, weight at birth, delivery by C-section, season of birth, medication for intestinal parasites, vitamin A supplementation, and nutritional status (stunting and wasting)).

Respondents were asked how often they listened to the radio or watched television in this study. Those who responded at least once a week are considered regularly exposed to that form of media [22]. Piped water (piped water, piped into a dwelling, piped to yard/plot, public tap/standpipe), tube well (tube well water, tube well or borehole), and other sources of drinking water were identified (e.g. rainwater, river, protected or unprotected well) [26]. Improved (flush toilet, flush to piped sewer system, flush to septic tank, flush to pit latrine, pit latrine with slab, and ventilated improved pit latrine), shared (improved but shared with other households), and not improved (no flush toilet, no flush to piped sewer system, no flush to septic tank, no flush to septic tank, no flush to septic tank, no flush to septic tank, no flush to septic tank (e.g. hanging toilet, open pit) [27]. Wealth index was re-categorized into high economic class (upper 20% asset value), middle economic class (middle 40% asset value) and low economic class (lower 40% asset value) [28]. The survivor also observed the main material of the floor/roof/wall of the dwelling. The floor/roof/wall was classified as natural (earth/sand and dung), rudimentary (wood planks and palm/bamboo) and finished (vinyl or asphalt strips, ceramic tiles, cement, and carpet) [22].

The BDHS obtained vaccination coverage data in two methods in 2017-18: from immunization cards provided to interviewers and from mothers' verbal remarks. The interviewers transcribed the vaccination dates straight into the questionnaire if the cards were available. The respondent was asked to recollect the immunizations administered to her child if there was no vaccination card for the child or if a vaccine had not been noted as being given on the vaccination card [22]. Mother's/household head’s educational level was also divided into three groups: no education, primary and secondary complete or higher (completing at least grade 10). Mother's BMI was classified as underweight (BMI less than 18.5 kg/m2), normal (BMI 18.5-24.9 kg/m2), overweight (BMI 25-29.9 kg/m2) and obese (BMI higher than 30 kg/m2) [29]. Mother's/household head’s occupation categorized as agricultural/skilled worker (farming/agricultural work and semi-skilled labor/service), household/unskilled worker (unskilled labor, home-based manufacturing, domestic service, and other), industrial worker (Professional/technical, business, factory work or blue-collar service, poultry or cattle raising).

In this study, weight at birth classified as low if the weight of child was less than 2500 grams and normal if greater than 2500 grams. For measuring a child's nutritional status, two anthropometric indices, height-for-age and weight-for-height z-score, were used as recommended by the WHO [30]. The z-score implies how many standard deviations a given value is apart from the mean, and it is usually used to standardize data. In this case, the z-score was utilized to compare stunting and wasting in children under the age of five across gender and age categories. A child was considered wasted if the weight-for-height z-score was less than -2 and stunted if the height-for-age z-score was less than -2. Some of the variables were re-categorized by combining two or more levels of individual variables.

**Statistical analyses**

Descriptive statistics were performed to show the distribution of variables. In this study, number and percentage were used for categorical variables. Chi square test was used to identify factors association with ARI in the children. ‘P’ value <0.05 was taken as significant and ‘P’ value <0.001 was taken as highly significant. We fitted the design-based binary logistic regression [31] to assess the association between child ARI and types of cooking fuel in household. For the adjusted association, the model was adjusted for type of cooking fuel, type of roof material, child's age (months), and sex of child. The crude odds ratio (COR) and adjusted odds ratio (AOR) were calculated, along with the 95% confidence interval (CI) and p-values. The specified predictor variables were used in a multiple logistic regression. Bivariate analysis, primarily the Chi-squared test and bivariate logistic regression model, were used to evaluate the association between ARI and each other studied exposure/covariate. In the crude model, only the ARI and fuel type was used. For the adjusted model, other confounding variables with ARI were considered. The relationship between ARI and every other considered exposure/covariate was investigated individually by using bivariate analysis, mainly the Chi-squared test and bivariate logistic regression model. We used the multivariable logistic regression model to observe how exposure variable acts when the effect of all other risk factors associated with ARI are adjusted and vice versa. The multivariable logistic regression model was formed by the backward elimination process to identify significant risk factors of ARI. Considering cluster variation in our analysis, we fitted a multilevel model using the survey binary logistic regression model. The statistical analyses and data management for this study had been carried out using R (survey package).

**Variable selection**

Variables were selected in two stages. The Rao-Scott Chi-squared test (a design-adjusted variation of the Pearson Chi-squared test) [32] was used in the first stage since it accounts for the data's cluster-design effect. In total, 21 variables were significant with ARI at the 20% significance level (Table 1, 2 and 3). In the second stage, bivariate logistic regression was conducted separately for each of the 21 variables selected from the first stage, and their unadjusted odds ratio (OR) was examined (Table 6). In this stage, 16 variables were found to be significant at the 5% significance level.

A multivariable full model was formed with the selected predictor variables. The final model was then created using a manual stepwise backward elimination approach. The least significant variable was eliminated at each phase of the stepwise elimination process, and this process was repeated until all of the variables in the model were significant at the 5% significance level. To check that the final model was appropriately described, we repeated the backward elimination process by include all risk factors in the whole model, with variables reserved only if P was less than 0.05. Risk factors selected by the second approach were the same as the initial approach. In this stage, 4 variables were found to be significant at the 5% significance level.

We used the variance inflation factor (VIF) value to examine multicollinearity in the final model with a cut-off value of 4.00 (Table 4). To check the predictive accuracy of the final model, the area under the curve (AUC) of the receiver operating characteristic curve was used (Table 5). We also used the Hosmer and Lemeshow goodness-of-fit test to provide an overview of the overall fit of the final model (Table 5).

**Results**

**Study sample characteristics**

The study team approached 20250 houses, and 20160 households were eligible for interview. Floodwater totally undermined three clusters, resulting in the loss of 90 households. As such, 20160 households with 8347 children were enrolled in the study from those 26 children eliminated due to visitors and non-surviving children. Finally, 8321 observation was obtained for this study (Figure 1).

**Socio-demographic characteristics**

Table 1 contains the results of chi-square analysis for identifying household factors associate with ARI. The results of the chi-square analysis indicated that types of the region of the country, media accessibility, toilet facility, types of cooking fuel, wealth index, electricity accessibility, types of roof material, types of wall material are significant factors as p-value is less than 0.05. Among 8321 children, 25.38% were from Dhaka, 51.76% of household had media accessibility, 70.52% had unimproved toilet facility, 41.77% from the poorest households, 78.97% used solid cooking fuel and 82.32% had electric accessibility.

Most of the mother (79.68%) of the children are from 15-24 years age group and a large group of mothers were vaccinated. As for parents’ characteristics, 48.64% of respondents were primary completed, 77.89% of household heads were industrial worker, and 49.29% of household heads had no education (Table 2).

In total, 58.47% of children were included from 24-59 age group. There were 52.16% of male children and 30.72% were stunt. The birth order distribution of children was 87.5% in 1-3 group, 59.3% born at health facility, 69.95% delivered at normal weight, and 66.61% children delivered by normal delivery (Table 3).

**Use of biomass fuel at household level**

In total, 78.97% of households used solid fuel: 43.8% used wood, 0.6% used straw 27.9% used crop, and 0.1% used cow dung (Figure 2). Children in the Rangpur and Barisal regions of Bangladesh had the highest prevalence of ARI, whereas the lowest prevalence was seen in Khulna. Similarly, Children in the Rangpur and Barisal regions of Bangladesh had the highest prevalence of solid fuel, whereas the lowest prevalence was seen in Dhaka (Figure 3). According to the results of the Rao-Scott Chi-squared independence test (Table 1), the prevalence of ARI is significantly associated (P <0.05) with the type of fuel used in the home.

**Model evaluation**

In the final multivariable logistic model, the VIF value revealed no multicollinearity (Table 4). The AUC value of 0.61 in table 5 indicates that the classification accuracy is fairly acceptable. Furthermore, the model passed the Hosmer and Lemeshow goodness-of-fit test (value = 8.2419, degrees of freedom = 8, P-value = 0.760), did not find any lack of fit in the model.

**Association between the prevalence of ARI and solid fuel**

Table 6 shows the crude and adjusted association between household fuel use and ARI among under children in Bangladesh. In crude analysis, solid fuel risk group in household fuel type was associated with 1.693 times higher odds of ARI than clean fuel risk group (COR: 1.693; 95% CI: 1.058–2.709). After adjusting the model for potential confounders and risk factors, we observed 1.692 times the odds of ARI among those children from solid fuel risk group in household than those from clean fuel (AOR: 1.692; 95% CI: 1.053–2.718).

**Discussion**

Of the study households, solid fuel (Coal/lignite, charcoal, wood, straw/shrubs/grass, agricultural crops, and animal dung) was the most widely used fuel for cooking in Bangladesh. Fewer households use electricity and LPG as cooking fuel. These findings show an association between the usage of solid fuel in the household and ARI episodes in children under the age of five. The prevalence of ARI was greater in children who lived in household that used solid fuel. A recent national representative sample of a Bangladesh Urban Health Survey conducted in 2013 reported 39.5% solid fuel user in urban areas and 60.5% are clean fuel user [33]. In India and Nepal, more than half of the households used solid fuel for cooking: 54% in India (2015-2016) and 66% in Nepal (2016). The lowest level of HAP was reported in Indonesia, at 23% in 2016 [34]. These proportions of biomass fuel use are similar to the results of the present study.

The association between use of biomass fuel and a higher rate of ARI has important implications for reducing the incidence of ARI and resulting morbidity and mortality. In our study, we found that ARI is more frequent in the children of uneducated mother. A study by the Department of International Health, Johns Hopkins University [35] found that most mothers believed that a ‘wind-carrying disease can kill their child whereas ARI is considered to be more manageable and this is the result of illiteracy. Government effort to educate girls beyond secondary level is therefore called for. The government’s free primary and secondary educational program is very relevant in this case and hence should be strengthened and be propelled to higher levels [36]. This is probably because mothers utilizing immunization services are better aware of health care facilities and probably seek early consultation for illness of their children, which probably avoids severe illness [37].

Our findings show that women in older age cohorts, as compared to those in the 15-24 age group, and those with a higher birth order, as compared to the first, have a lower risk of ARI. This can be attributed to the knowledge and experience concerning childcare accumulated by older women over time which unambiguously gives them an edge over younger women [36].Household wealth was defined according to the respondents reported household assets and was assigned a standardized score and was categorized into three categories namely, lower, middle and higher. Overweight (BMI 25 kg/m2) is a growing problem which has been associated risk for acute respiratory infections [38].The incidence and severity of infectious illnesses are higher in obese persons than in lean persons. Acute respiratory infection is found to be the most significantly associated factor with malnutrition during childhood.

In our study, the incidence of ARI was higher in stunted infants, wasted infants and infants that have low birth weight .Stunting is related to the long time exposure to poor environmental conditions and low socioeconomic status in childhood [39].The frequent and longer episodes of ARI may cause the retardation of growth. Moreover, other nutritional disorders are also associated with ARI. Presence of malnutrition was significantly associated with ARI in the present study, similar to other studies [15]. A study in the Philippines included age stratified risks in children less than 23 month of age and reported highest risk of death from ARI due to malnutrition among those aged 12-22 month [14]. A study in New Delhi revealed severe malnutrition as the predictor of mortality in ARI in 2 weeks to 5 years old children. Overall malnutrition has been associated with  two- to three-fold increase in ARI mortality [40].

Although the studies differ in terms of design, exposure measurement, and outcome evaluation, the current findings concerning the relationship between solid fuel consumption and ARI incidence are similar to most studies from India (OR 4.0, 95% CI 2.0e7.9), Nepal (OR 2.3, 95% CI 1.8-2.9) Zimbabwe (OR 2.1, 95% CI 1.5-3.1), Gambia (OR 5.2, 95% CI 1.7-15.9), and a metanalysis of these studies (OR 2.3, 95% CI 1.9-2.7)

**Strengths and limitations**

To the best of our knowledge, this is the first study to assessed the association between exposure to solid fuel and ARI episodes among children aged under 5 years in Bangladesh. We used a sufficiently large nationally representative dataset that reflects Bangladesh's whole population. We also took into account a wide range of factors that influence the public's knowledge of the issue. We also looked at model-fitting criteria, which were mostly absent in the literature. Despite this, there were certain limits to our research. Because we used secondary data, we had no control over variable selection, data quality, or measurement indications. In this study, environmental and behavioral factors was missing, which is important in exposure assessment. Furthermore, the study was performed three years ago; in that period, the level fuel used among household may have shifted.

**Conclusion**

The current study yields solid evidence that solid fuel significantly increases children’s risk of ARI in Bangladesh. Despite the limitations discussed above, the strength of the association and the frequency of reporting of fuel type as the main reason for ARI are remarkable enough to warrant the conclusion that solid fuel is a main driver of ARI in Bangladesh. This finding underscores the need to improve cooking fuel in order to reduce ARI disease in many parts of the country. Our study also suggests that ARI, which is already at a very large scale, is increasing at the double. Government should invest greater resources in ARI prevention and control, and explicitly consider ARI as a top priority phase and scenario.

**Conflict of interest**

No conflict of interest

**Author`s contribution**

**Mohammad Nayeem Hasan:** Conceptualization, Supervision, Methodology, Formal Analysis, Writing-Reviewing and Editing. Tanvir Ahammed Tonmoy: Methodology, Formal Analysis, Writing-original draft. Aniqua Anjum: Methodology, Writing-Reviewing and Editing. Sabrin Sultana: Writing-Reviewing and Editing. M. Noor-E-Alam Siddiqui: Methodology, Writing-Reviewing and Data curation.

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**Tables and figures**

Table 1 Frequency distribution of households (weighted\*) on use of solid fuel and acute respiratory infection (ARI) among children younger than 5 years in Bangladesh.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Factors | ARI | | | |  |
| Yes, N (%) | | No, N (%) | Total, N (%) | P-value |
| **Total** | **250 (3.00)** | | **8071 (97.00)** | **8321 (100.00)** |  |
| **Place of residence** |  | |  |  |  |
| Urban | 57 (2.56) | | 2186 (97.44) | 2243 (26.96) | 0.188 |
| Rural | 192 (3.17) | | 5885 (96.83) | 6078 (73.04) |  |
| **Region of the country** |  | |  |  |  |
| Barisal | 19 (4.16) | | 443 (95.84) | 462 (5.55) | <0.001 |
| Chittagong | 48 (2.76) | | 1698 (97.24) | 1746 (20.99) |  |
| Dhaka | 42 (1.97) | | 2070 (98.03) | 2111 (25.38) |  |
| Khulna | 13 (1.74) | | 754 (98.26) | 768 (9.23) |  |
| Mymensingh | 17 (2.38) | | 688 (97.62) | 705 (8.48) |  |
| Rajshahi | 38 (3.94) | | 933 (96.06) | 971 (11.67) |  |
| Rangpur | 53 (5.98) | | 826 (94.02) | 879 (10.56) |  |
| Sylhet | 20 (2.95) | | 658 (97.05) | 679 (8.15) |  |
| **Media accessibility** |  | |  |  |  |
| Yes | 139 (3.65) | | 3661 (96.35) | 3800 (51.76) | 0.002 |
| No | 80 (2.26) | | 3461 (97.74) | 3541 (48.24) |  |
| **Source of drinking water** |  | |  |  |  |
| Piped water | 5 (1.12) | | 481 (98.88) | 486 (6.63) | 0.089 |
| Tube well | 206 (3.11) | | 6423 (96.89) | 6629 (90.30) |  |
| Other | 7 (3.13) | | 219 (96.87) | 226 (3.07) |  |
| **Toilet facility** |  | |  |  |  |
| Improved | 43 (2.01) | | 2121 (97.99) | 2164 (29.48) | 0.002 |
| Unimproved | 175 (3.39) | | 5001 (96.61) | 5177 (70.52) |  |
| **Type of cooking fuel** | |  |  |  |  |
| Clean fuel | 30 (1.95) | | 1512 (98.05) | 1542 (21.03) | 0.027 |
| Solid fuel | 189 (3.25) | | 5603 (96.75) | 5792 (78.97) |  |
| **Wealth index** |  | |  |  |  |
| Higher | 74 (2.27) | | 3201 (97.73) | 3276 (39.36) | 0.001 |
| Middle | 40 (2.56) | | 1529 (97.44) | 1569 (18.86) |  |
| Lower | 135 (3.89) | | 3341 (96.11) | 3476 (41.77) |  |
| **Electricity accessibility** |  | |  |  |  |
| No | 56 (4.11) | | 1315 (95.89) | 1371 (18.68) | 0.023 |
| Yes | 162 (2.72) | | 5808 (97.28) | 5970 (81.32) |  |
| **Type of flooring material** |  | |  |  |  |
| Natural | 155 (3.35) | | 4472 (96.65) | 4672 (63.02) | 0.091 |
| Rudimentary | 2 (2.80) | | 68 (97.20) | 68 (0.96) |  |
| Finished | 62 (2.33) | | 2582 (97.67) | 2582 (36.02) |  |
| **Type of roof material** |  | |  |  |  |
| Natural | 1 (2.69) | | 50 (97.31) | 51 (0.69) | 0.008 |
| Rudimentary | 1 (27.26) | | 2 (72.74) | 3 (0.04) |  |
| Finished | 217 (2.97) | | 7071 (97.03) | 7287 (99.27) |  |
| **Type of wall material** |  | |  |  |  |
| Natural | 24 (3.88) | | 605 (96.12) | 629 (8.57) | 0.042 |
| Rudimentary | 17 (5.48) | | 298 (94.52) | 315 (4.29) |  |
| Finished | 177 (2.77) | | 6220 (97.23) | 6397 (87.13) |  |
| **Number of household member** |  | |  |  |  |
| Below median | 80 (2.94) | | 2653 (97.06) | 2733 (32.85) | 0.855 |
| Above median | 169 (3.03) | | 5418 (96.97) | 5588 (67.15) |  |

\*Frequencies are weighted using sample weight

Table 2 Frequency distribution of parents (weighted\*) on use of solid fuel and acute respiratory infection (ARI) among children younger than 5 years in Bangladesh

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Factors | ARI |  |  |  |
|  | Yes, N (%) | No, N (%) | Total, N (%) | P-value |
| **Total** | **250 (3.00)** | **8071 (97.00)** | **8321 (100.00)** |  |
| **Mothers age group (in years)** |  |  |  |  |
| 15-24 | 126 (3.19) | 3824 (96.81) | 3950 (47.47) | 0.722 |
| 25-34 | 105 (2.81) | 3613 (97.19) | 3718 (44.68) |  |
| 45+ | 19 (2.97) | 634 (97.03) | 654 (7.86) |  |
| **Vaccination** |  |  |  |  |
| Yes | 43 (3.33) | 1252 (96.67) | 1295 (79.68) | 0.014 |
| No | 3 (0.77) | 328 (99.23) | 330 (20.32) |  |
| **Mother’s education level** |  |  |  |  |
| Secondary or Higher | 29 (2.18) | 1287 (97.82) | 1316 (15.81) | 0.221 |
| Primary | 127 (3.14) | 3920 (96.86) | 4047 (48.64) |  |
| No Education | 94 (3.18) | 2864 (96.82) | 2958 (35.55) |  |
| **Mother’s BMI** |  |  |  |  |
| Obese | 10 (2.07) | 477 (97.93) | 487 (5.96) | 0.719 |
| Overweight | 54 (3.20) | 1624 (96.80) | 1678 (20.53) |  |
| Normal Weight | 150 (3.07) | 4734 (96.93) | 4734 (59.73) |  |
| Under Weight | 34 (3.04) | 1093 (96.96) | 1093 (13.79) |  |
| **Number of living children** |  |  |  |  |
| <=2 | 178 (3.00) | 5751 (97.00) | 5929 (71.26) | 0.990 |
| 3-4 | 62 (3.03) | 1994 (96.97) | 2056 (24.71) |  |
| 5+ | 10 (2.88) | 326 (97.12) | 336 (4.03) |  |
| **Mother’s occupation** |  |  |  |  |
| Agriculture | 87 (3.64) | 2314 (96.36) | 2401 (28.86) | 0.026 |
| Don’t work | 121 (2.52) | 4670 (97.42) | 4791 (57.59) |  |
| Industires | 42 (3.72) | 1085 (96.28) | 1127 (13.55) |  |
| **Mother’s work for** |  |  |  |  |
| Family | 88 (4.05) | 2077 (94.95) | 2165 (61.43) | 0.111 |
| Else | 15 (2.23) | 641 (97.77) | 655 (18.59) |  |
| Self | 27 (3.83) | 677 (96.17) | 704 (19.98) |  |
| **Household head’s occupation** |  |  |  |  |
| Agriculture | 62 (3.73) | 1590 (96.27) | 1651 (19.89) | 0.185 |
| Don’t work | 4 (1.95) | 181 (98.05) | 184 (2.22) |  |
| Industries | 185 (2.86) | 6283 (97.14) | 6468 (77.89) |  |
| **Household head’s education** |  |  |  |  |
| Secondary or Higher | 25 (1.70) | 1436 (98.30) | 1461 (17.87) | 0.017 |
| Primary | 85 (3.15) | 2600 (96.85) | 2685 (32.84) |  |
| No Education | 137 (3.40) | 3892 (96.60) | 4029 (49.29) |  |
| **Type of household head’s education** |  |  |  |  |
| School | 216 (3.10) | 6766 (96.90) | 6982 (90.36) | 0.969 |
| Madrasha | 23 (3.13) | 721 (96.87) | 745 (9.64) |  |

\*Frequencies are weighted using sample weight

Table 3 Frequency distribution of children (weighted\*) on use of solid fuel and acute respiratory infection (ARI) among children younger than 5 years in Bangladesh

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Factors | ARI |  |  |  |
|  | Yes, N (%) | No, N (%) | Total, N (%) | P-value |
| **Total** | **250 (3.00)** | **8071 (97.00)** | **8321 (100.00)** |  |
| **child's age (months)** |  |  |  |  |
| 24-59 | 112 (2.29) | 4753 (97.71) | 4865 (58.47) | <0.001 |
| 12-23 | 69 (4.09) | 1611 (95.91) | 1680 (20.19) |  |
| 0-11 | 70 (3.92) | 1706 (96.08) | 1776 (21.34) |  |
| **Sex of Child** |  |  |  |  |
| Male | 155 (3.58) | 4185 (96.42) | 4340 (52.16) | 0.003 |
| Female | 95 (2.38) | 3886 (97.62) | 3981 (47.84) |  |
| **Birth Order** |  |  |  |  |
| 1-3 | 210 (2.88) | 7074 (97.12) | 7284 (87.54) | 0.074 |
| 4-6 | 39 (4.04) | 935 (95.96) | 935 (11.71) |  |
| 6+ | 1 (0.98) | 62 (99.02) | 62 (0.75) |  |
| **Place of delivery** | | | | |
| Home | 93 (3.62) | 2468 (96.38) | 2561 (50.09) | 0.337 |
| Hospital | 79 (3.09) | 2472 (96.51) | 2551 (59.91) |  |
| **Weight at birth** | | | | |
| Low birth weight | 21 (3.03) | 677 (96.97) | 698 (30.05) | 0.762 |
| Normal birth weight | 53 (3.29) | 1572 (96.71) | 1625 (69.95) |  |
| **Delivery by C-section** |  |  |  |  |
| Yes | 49 (2.86) | 1656 (97.14) | 1705 (33.39) | 0.208 |
| No | 123 (3.61) | 3278 (96.39) | 3401 (66.61) |  |
| **Season of birth** |  |  |  |  |
| Summer | 73 (3.40) | 2077 (96.60) | 2150 (25.84) | 0.051 |
| Autumn | 46 (2.46) | 1829 (97.54) | 1875 (22.53) |  |
| Winter | 75 (3.70) | 1942 (96.30) | 2016 (24.23) |  |
| Spring | 56 (2.45) | 2224 (97.55) | 2279 (27.39) |  |
| **Medication for intestinal parasites** |  |  |  |  |
| No | 168 (3.41) | 4759 (96.59) | 4927 (59.24) | 0.145 |
| Yes | 82 (2.41) | 3301 (97.59) | 3382 (40.71) |  |
| **Vitamin A supplementation** |  |  |  |  |
| No | 66 (2.96) | 2170 (97.04) | 2236 (26.95) | 0.883 |
| Yes | 184 (3.03) | 5879 (96.97) | 6063 (73.05) |  |
| **Stunting** |  |  |  |  |
| No | 159 (2.94) | 5258 (97.06) | 5417 (69.28) | 0.217 |
| Yes | 85 (3.54) | 2316 (96.46) | 2402 (30.72) |  |
| **Wasting** |  |  |  |  |
| No | 221 (3.09) | 6924 (96.91) | 7145 (91.56) | 0.496 |
| Yes | 24 (3.60) | 635 (96.40) | 659 (8.44) |  |

\*Frequencies are weighted using sample weight

Table 4Generalized variance inflation (GVIF) value of the final model of ARI among under 5 years children in Bangladesh

|  |  |  |
| --- | --- | --- |
| Variables | Degrees of freedom | GVIF |
| **Type of cooking fuel** | 1 | 1.01 |
| **Type of roof material** | 2 | 1.02 |
| **child's age (months)** | 2 | 1.02 |
| **Sex of Child** | 1 | 1.02 |

Table 5Test for goodness of fit and predictive accuracy of the final model

|  |  |  |
| --- | --- | --- |
| Hosmer and Lemeshow goodness of fit test | | |
| Value | df | P-value |
| 8.2419 | 8 | .760 |
| Area under the curve (AUC) of the receiver operating characteristic curve (ROC) | | |
| Value | 0.61 | |

Table 6 Association between household type of fuel use and ARI among under 5 years children in Bangladesh

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Unadjusted model | | | Adjusted model1 | | |
| Variables |  | COR | 95% CI | P-value | AOR | 95% CI | P-value |
| **Type of cooking fuel** | Solid fuel | 1.693 | [1.058, 2.709] | 0.028 | 1.692 | [1.053, 2.718] | 0.030 |
|  | Clean fuel | 1 |  |  | Ref. |  |  |

*COR crude odds ratio, AOR adjusted odds ratio, CI confdence interval, Ref. reference*

1The adjusted analysis using the design-based binary logistic regression, adjusted for type of cooking fuel, Type of roof material, child's age (months), and sex of child.

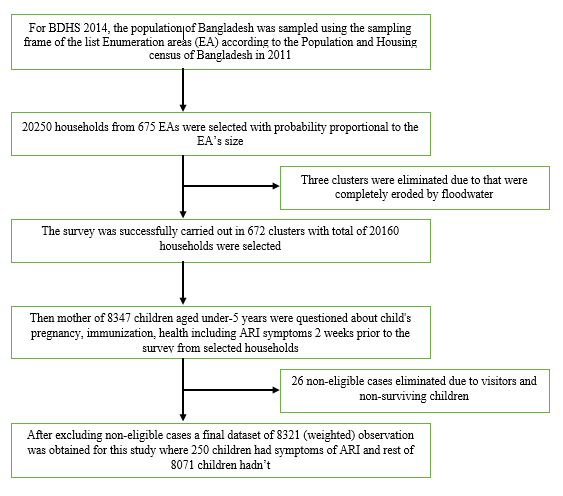


Figure 1 Sample procedure of 2017 BDHS and selection of sample for the study



Figure 2 Fuel types used in study area. LPG, liquefied petroleum gas



Figure 3 Prevalence of acute respiratory infection (ARI) in different regions of Bangladesh