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Indoor exposure to particulate matter and the incidence of acute lower respiratory infections among children: A birth cohort study in urban Bangladesh

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Abstract

Background—Approximately half of all children under two years of age in Bangladesh suffer from an acute lower respiratory infection (ALRI) each year. Exposure to indoor biomass smoke has been consistently associated with an increased risk of ALRI in young children. Our aim was to estimate the effect of indoor exposure to particulate matter ($PM_{2.5}$) on the incidence of ALRI among children in a low-income, urban community in Bangladesh.

Methods—We followed 257 children through two years of age to determine their frequency of ALRI and measured the $PM_{2.5}$ concentrations in their sleeping space. Poisson regression was used to estimate the association between ALRI and the number of hours per day that $PM_{2.5}$ concentrations exceeded 100 μg/m^3, adjusting for known confounders.

Results—Each hour that $PM_{2.5}$ concentrations exceeded 100 μg/m^3 was associated with a 7% increase in incidence of ALRI among children aged 0 – 11 months (adjusted IRR 1.07, 95% CI 1.01 – 1.14), but not in children 12 – 23 months old (adjusted IRR 1.00, 95% CI 0.92 – 1.09).

Conclusions—Results from this study suggest that reducing indoor $PM_{2.5}$ exposure could decrease the frequency of ALRI among infants, the children at highest risk for death from these infections.

Keywords

respiratory infection; particulate matter; indoor air pollution; incidence; Bangladesh

Introduction

Acute lower respiratory infection (ALRI) is the leading cause of death in children younger than five years of age in Bangladesh (Black et al., 2010). ALRI causes approximately 21% of all deaths in children younger than five years in Southeast Asia (Black et al., 2010). Children under five years of age in Bangladesh suffer an estimated 0.2 – 0.5 episodes of ALRI per child per year (Brooks et al., 2010; Zaman et al., 1997).

The burden from ALRI extends beyond morbidity and mortality. Evidence from Kenya suggests that increased frequency of ALRI and diarrhea in toddlers aged 18–30 months was associated with lower Bayley Mental development scores at 30 months and lower cognitive scores at 5 years of age for girls (Neumann et al., 1991). High costs associated with hospitalizations from childhood ALRI can also have a negative impact on household nutrition and education. A study of children hospitalized with ALRI in Dhaka showed that 50% of families would have to reduce household spending on food and education to cover hospitalization-related costs (Alamgir et al., 2010).

In a recent meta-analysis, exposure to indoor biomass smoke was associated with a 1.8-fold increase in the risk of developing ALRI among young children (Dherani et al., 2008). Smoke from biomass cooking fires is an important source of respirable particulate matter (PM) for children in low income countries (Smith et al., 2000). Studies of both rural and urban households in Bangladesh suggest that even households that use cleaner fuels for cooking, such as natural gas, may experience indoor PM levels many times higher than health concentrations recommended by the World Health Organization (World Health Organization, 2006; Dasgupta et al., 2006).

Despite the consistent evidence that indoor exposure to PM can increase the risk of ALRI in children, the relationship remains poorly characterized. One reason for this is that all but a few epidemiologic studies studying this relationship have used household cooking with biomass fuel as a proxy for child exposure to PM rather than actual measurements of PM exposure (Dherani et al., 2008). Therefore, little is known about the concentrations of indoor PM children were exposed to in these studies or the effect of the level of exposure on the incidence of ALRI. Importantly, use of this proxy measurement for exposure also means that little is known about exposures to PM in households that burn cleaner fuels and the effect of this exposure on ALRI.

The objective of this study was to estimate the independent effect of indoor exposure to measured PM concentrations on the incidence of ALRI among children in a low-income urban community in Dhaka, Bangladesh, and to investigate how this effect varied with age.

Methods

Enrollment in the birth cohort

Mirpur is a densely populated, low-income, urban community in Dhaka, Bangladesh (Haque et al., 2001). Researchers identified pregnant women in this community through household visits and enrolled their newborns in a cohort study to investigate the incidence and etiology of childhood enteric infections and their associations with cognitive development. All children born in the study area from January 2008 through April 2009 were eligible to participate in the birth cohort and all children enrolled in this birth cohort were eligible to participate in our study to examine the relationship between indoor air pollution and acute respiratory infections.

Child follow-up and surveillance for acute lower respiratory infections

Trained research assistants visited neonates within 72 hours of birth and measured their weight and length using a standard protocol. These anthropometric measurements were repeated at approximately 3 and 12 months of age. All enrolled children were continually visited in their homes every three to four days by trained community health workers until their second birthday. During home visits health workers inquired about signs or symptoms of illness that the child experienced since the last visit and about whether or not the child was still being exclusively breastfed. The child was referred to the study clinic if he or she was experiencing one major or two minor signs of respiratory illness the day of the visit. Major signs were reluctance to feed or drink, difficult breathing, cyanosis, or chest indrawing. Minor signs were fever, cough, or irritability (Brooks et al., 2010). Children could also seek care at the clinic anytime, without referrals from community health workers.

Study children lived within 1.5 kilometers from the study clinic and referral services were provided free of cost to participants. Children seen at the clinic were examined by pediatrician who recorded the symptoms reported by the mother or caretaker and conducted a physical examination of the child, including measurement of the respiratory rate. An episode of ARI was defined as a visit to the study clinic with any new sign of respiratory illness. An episode of ALRI was defined as a new episode of ARI that included new onset either cough or difficulty breathing with age-specific tachypnea or physician observed chest in-drawing or crepitations (World Health Organization, 2000). Tachypnea, or fast breathing, was defined as a measurement of >60 breaths per minute for children aged <2 months, ≥50 breaths per minute for children aged 2—11 months, and ≥40 breaths per minute for children aged 12—23 months (Taylor et al., 1995).

Measurement of household risk factors and indoor particulate matter levels

Children were enrolled in the study to investigate the association between respirable particulate matter exposure and incidence of ALRI during April 2009. No more than one child was enrolled per household. Every household with a child participating in the study was visited during April and May 2009 and characteristics of the household were recorded on a structured questionnaire, including the educational status of both parents; household ownership of cell phones and televisions; the number of people who lived in the house; the floor area of the living space; the number of windows and doors opening to the outside; the location of the cooking stove; the kind of fuels burned in the home for cooking or other purposes; and whether or not any household members smoked cigarettes in the house. Preliminary evidence from the study suggested that many households had specialized stoves for cooking with natural gas or electricity, but these cleaner fuel sources were sometimes unavailable due to regular power outages or limited natural gas supply. If cleaner fuels were unavailable, some households burned biomass, such as wood, bamboo or paper, in traditional stoves. Therefore, we conducted a survey during March 2011, at the end of the study, to collect data on all fuel types used by the household since May 2009 to capture this heterogeneity. Households that were not participating in the survey at the end of the study were categorized based on their baseline fuel use information.

The average concentrations of $PM_{2.5}$ in the child's sleeping space were measured to quantify their exposure, and these methods are published elsewhere (Gurley et al., 2012). In brief, once per month between May 2009 and April 2010, a PM air monitor manufactured by the Berkeley Air monitoring group (Smith et al., 2007) was placed in the child's sleeping space for a 24-hour period to measure concentrations of PM approximately less than 2.5 μm in diameter ($PM_{2.5}$). The limit of detection for these monitors was 50 μg/m^3 (Edwards et al., 2006).

Statistical analyses

Descriptive statistics were used to characterize the birth cohort children, their homes, and their ALRI episodes. We created fuel use categories to capture heterogeneity in fuel use based on the survey at the end of the study. We classified household fuel use during the study period as: clean fuels only (including both natural gas and electricity), biomass fuels only, or primarily clean but occasionally biomass fuels.

Incidence rates of ARI and ALRI were calculated with 95% confidence intervals. Incidence rates were calculated by dividing the total number of events occurring among children by the total amount of time that each child contributed to the analysis. Incidence rates were calculated for time contributed by children 0 – 23 months of age and separately for children 0 – 11 months and 12 – 23 months of age.

Incidence rate ratios were calculated using Poisson regression to investigate the bivariate relationships between measured risk factors and incidence of ALRI. Then, to estimate the independent risk associated with exposure to $PM_{2.5}$, a multivariate model was constructing including potential confounders described in the meta-analysis by Dherani, et al (Dherani et al., 2008), including socio-economic status, mother's education, crowding, breastfeeding, and malnutrition. Ownership of both a television and cell phone was used as an indicator of household wealth and this measurement combined with mother's education was used as a proxy for socio-economic status. Crowding was represented by the number of persons per square meter of household floor space. The World Health Organization recommends that children be exclusively breastfed for the first six months of age (Kramer and Kakuma, 2009). We created a binary variable to classify children as either being exclusively breastfed according to recommendations or not. Because children were unlikely to be breastfed for exactly 6 months, our definition of appropriate breastfeeding included children who were breastfed for at least 5 but not more than 6.3 months. We included both low birth weight and wasting as indicators of child nutrition. Wasting was defined as a weight for age z score less than −2 and we included the measurement at 3 months of age in the model for children aged 0 – 11 months and the measurement at 12 months for children aged 12 – 23 months.

Exposure to indoor tobacco smoke and vaccination status were also proposed as possible confounders of the relationship between biomass smoke exposure and ALRI (Dherani et al., 2008). However, exposure to indoor cigarette smoking was not included in the multivariate analysis because we considered indoor tobacco smoke to be a contributor to our measurements of $PM_{2.5}$, not a confounder. We did not include vaccination status in the model because coverage of measles, diphtheria, and pertussis vaccines were >95% among cohort children (R. Haque, personal communication). At the time this study was conducted, neither influenza virus nor pneumococcal vaccines were included in the immunization schedule or available commercially on the local market. *Haemophilus influenzae* type b vaccines were not included in the immunization schedule but were commercially available in the study community for approximately US $7 per dose (NS Kakoly, personal communication). However, we did not collect information about *Haemophilus influenzae* type b vaccination status from study children.

$PM_{2.5}$ concentration measurements from each child's sleeping space were summarized to calculate the mean number of hours that the $PM_{2.5}$ concentration exceeded 100 μg/m^3 (daily hours >100 μg/m^3). The threshold of 100 μg/m^3 does not represent a known threshold associated with poorer health outcomes but was chosen for exploratory analyses because it represented twice the limit of detection of the monitors and four times the World Health Organization guidelines for indoor air quality (25 μg/m^3 daily mean) (World Health Organization., 2006).

The assumption of the Poisson regression model that the variance equaled the mean was confirmed by fitting the models using a negative binomial distribution and assessing whether or not the dispersion parameter was significantly different from zero. Associations were considered statistically significant for p-values < 0.05.

Human subject considerations

Prior to enrollment, all mothers provided either a signature or a thumb print indicating their informed consent for participation. Institutional Review Boards at the following institutions reviewed and approved the protocol: icddr,b, Dhaka, Bangladesh (formerly known as the International Centre for Diarrheal Diseases Research, Bangladesh); University of Virginia, Charlottesville, VA; US Centers for Disease Control and Prevention, Atlanta, GA; and Johns Hopkins Bloomberg School of Public Health, Baltimore, MD.

Results

Two hundred and sixty-two newborns were enrolled in the birth cohort and also agreed to participate in our study to investigate indoor exposure to particulate matter and the incidence of ALRI. Complete baseline characteristics were available for 257 (98%) children and these were included in the analysis. Thirty-six percent were born weighing <2500 grams. Households were crowded, with 1.8 square meters of floor space per person. Only 6% of households cooked with biomass exclusively, although 52% reported occasional use of biomass fuel, including wood, bamboo, jute and paper. (Table 1) Twenty-one percent (52/257) of households were not available for the endline survey on fuel use so they were categorized according to their fuel use behaviors captured at baseline. $PM_{2.5}$ concentrations exceeded 100 μg/m^3 for a median of 5.3 hours per day (interquartile range 4.0 – 6.9) for all study homes.

The 257 children were observed for 491 child-years; each child contributed a mean of 1.9 years to the analysis. These 257 children experienced 969 episodes of ARI, 381 (39%) of which were ALRI. Sixty-six percent of children (169/257) experienced at least one ALRI by two years of age (Table 2). No children were referred to the hospital or died due to respiratory disease during the study. The majority of the 381 ALRI episodes we observed included crepitations (65%, 247/381) and 42% (158/381) included chest indrawing (Table 3). The incidence of ARI did not vary between age groups, however, there were differences in the incidence of ALRI by age. The ALRI incidence rate for children aged 0 – 11 months was 43% higher than for children aged 12 – 23 months (0.9 vs. 0.6, p-value <0.001) (Table 4).

In bivariate analysis, low birth weight was associated with a 37 – 40% increase in ALRI risk overall and within each age group (Table 5). Being wasted and male were associated with increased incidence of ALRI overall, but not within the individual age groups. Each additional hour per day, on average, that $PM_{2.5}$ exceeded 100 μg/m^3 was significantly associated with a 7% increase in ALRI risk among children 0 – 11 months old. (Table 5)

In the multivariate model for children aged 0 – 23 months, being born low birth weight was associated with a 39% increase in risk for ALRI (IRR 1.39, 95% CI 1.07 – 1.82, P = 0.02). Male sex was also independently associated with a 23% (IRR 1.23, 95% CI 1.00 – 1.51, P = 0.05) increased risk in this age group. Indoor $PM_{2.5}$ concentrations were not associated with risk for ALRI among children aged 0 – 23 months (IRR 1.04, 95% CI 0.99 – 1.09). For children 0 – 11 months of age, each hour that $PM_{2.5}$ concentrations exceeded 100 μg/m^3 was independently associated with a 7% increase in ALRI incidence (IRR 1.07, 95% CI 1.01 – 1.14, P = 0.03), and being born low birth weight was associated with a 46% increase in risk (IRR 1.46, 95% CI 1.03 – 2.06, P = 0.03). Neither PM exposure nor any other risk factors were independently associated with ALRI incidence in children aged 12 – 23 months. (Table 6) When we fitted the same models with a negative binomial distribution, the mean was not different from the variance indicating that the Poisson model was a good fit for the data.

Discussion

In this study each hour that $PM_{2.5}$ concentrations in the space where the child slept exceeded 100 μg/m^3 was independently associated with a 7% increase in incidence of ALRI among children younger than 12 months of age, but there was no association between $PM_{2.5}$ exposure and ALRI in children aged 12 – 23 months. Results from our study suggest that infants may suffer more harmful effects from $PM_{2.5}$ exposure than older children. Many authors have hypothesized that younger children may be at higher risk of poor health due to inhalation of particulate matter than older children (Mauderly, 2000; Naeher et al., 2007), either because of relatively faster ventilation compared to body size, less well developed immune responses, or relatively smaller airway volume, although scientific evidence supporting this increased risk is lacking (Mauderly, 2000; Schwartz, 2004). The incidence rate ratio for $PM_{2.5}$ exposure from the bivariate analysis remained essentially unchanged in the multivariate model suggesting a lack of confounding by known confounders, likely because children with high PM exposure in this community are similar to children with relatively lower PM exposure in terms of other risks for ALRI. It is important to note that we did not observe any hospitalizations or deaths in our study children. Children were able to access high quality care early in their illnesses which likely reduced the likelihood of them developing a more severe illness. This kind of early intervention and close management of childhood ALRI in this study provided good incidence data on physician diagnosed ALRI; however, our ability to comment on the association between PM exposure and more severe health outcomes is limited because of this early medical intervention.

Even though 42% of households burned exclusively clean fuels, $PM_{2.5}$ concentrations exceeded 100 µg/m^3 for an average of 5.3 hours per day. Evidence from Bangladesh suggests that indoor exposures to particulate matter are determined both by the fuel used for cooking as well as ambient pollution levels, particularly for households that cook with cleaner fuels (Dasgupta et al., 2006). In our study community, the most important determinant of indoor $PM_{2.5}$ concentrations was season, and not cooking fuel type (Gurley et al., 2012). Additional research to better understand the contribution of ambient PM to indoor concentrations in these homes could be useful in designing interventions to reduce PM exposure and reduce ALRI in this and similar settings.

Low birth weight was common among children in this cohort (36%) and its effect on ALRI risk was substantial. There are numerous etiologies of low birth weight (Valero De Bernabe et al., 2004) and some study findings suggest that exposure to indoor air pollution could be one contributor (Shah and Balkhair, 2011; Stieb et al., 2012). The relationship between indoor exposure to PM and risk of low birth weight should be explored in this setting. Nutritional interventions for pregnant mothers have been shown to be effective at preventing low birth weight and these should be implemented to prevent subsequent risks for morbidity and mortality among children born underweight (Black et al., 2008; Black et al., 2003; Victora et al., 1999).

Male sex was associated with increased risk of ALRI for children aged 0 – 23 months, and there are two possible explanations for this association, besides chance alone. One study from Bangladesh showed that male neonates were twice as likely as female neonates to be taken to a trained care provider during illness (Ahmed et al., 2001), so care seeking patterns could have caused this difference. However, we did not systematically collect data on who did not come to the clinic after referral so we cannot assess whether male children were more likely to seek care from these referrals. It is more likely that the association we observed reflects actual increased risk among males. Male infants are biologically more susceptible to more severe respiratory disease caused by viruses such as respiratory syncytial virus (Simoes, 2003), or human metapneumovirus (Williams et al., 2004), as well as pneumococcal disease (Klein, 1981), perhaps due to their shorter and narrower airways (Martinez et al., 1988).

A strength of our study is that we measured $PM_{2.5}$ concentrations to characterize exposure, which allowed us to quantify the levels of $PM_{2.5}$ associated with increased risk of respiratory illness. However, our measurements of exposure to $PM_{2.5}$ have limitations. Children were enrolled as they were born in the community from January 2008 through April 2009 but our PM measurements did not begin until May 2009. Exposure measurements do not temporally overlap with many of the ALRI episodes we observed, resulting in potential non-differential misclassification of PM exposure status which could bias our measure of association towards a null finding. Despite this, we observed a strong association between PM exposure and ALRI. A second limitation is that indoor measurements of $PM_{2.5}$ are proxy measurements for the actual exposure to $PM_{2.5}$ for study children. We observed an association for infants but not for children over a year old and this could be because once children begin to walk they spend less time indoors and, therefore, our $PM_{2.5}$ exposure measurement is a better indicator of exposure for infants than older children. It is also possible that our findings resulted from unmeasured confounders; however, we attempted to account for all confounders identified from similar studies. Finally, indoor $PM_{2.5}$ measurements were not adjusted for relative humidity and devices that use light scattering technology to measure $PM_{2.5}$ concentrations have been shown to overestimate $PM_{2.5}$ when relative humidity exceeds 85% (Quintana et al., 2000). Nevertheless, monthly average relative humidity in Dhaka ranged from 45% – 79% throughout the year (http://www.dhaka.climatemps.com, accessed 2011), so an overestimation of $PM_{2.5}$ in our study seems unlikely. In addition, all household $PM_{2.5}$ measurements would have been equally affected by days when relative humidity exceeded 85% so this would be unlikely to affect the associations we observed in our analysis.

Ninety percent of the mortality among children younger than 5 years of age in Bangladesh occurs in children <12 months of age (El Arifeen, 2008), and the leading cause of death in these children is ALRI (Black et al., 2003). Studies to identify risks associated with increased frequency of ALRI in younger age groups at higher risk for mortality may be useful for designing life-saving interventions (Katz et al., 2003). Our findings suggest that efforts to reduce indoor $PM_{2.5}$ exposures in low-income, urban Bangladeshi homes could meaningfully reduce ALRI morbidity and mortality. PM concentrations in our study households were high, including in households that used cleaner fuels for cooking. Interventions to reduce reliance on biomass for cooking in this community would reduce exposures, but additional research is needed to understand how to best reduce PM exposures in homes that already burn clean fuels.

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Practical implications: Exposure to indoor biomass smoke has been consistently associated with an increased risk of acute lower respiratory infections in young children, but the nature of this relationship is not well characterized. In our study, every hour that average indoor particulate matter concentrations were above 100 μg/m^3 was associated with a 7% increase in risk of acute respiratory infection among infants; although, no increased risk was observed for older children. Reducing indoor exposure to particulate matter could reduce incidence of acute lower respiratory infections among infants, who are at highest risk for death from these infections.

Table 1

Baseline characteristics of children enrolled in the birth cohort in Mirpur, Dhaka, Bangladesh, January 2008 – April 2009 (N=257)

Child and household characteristics	N (%)
Children weighing <2500 grams within 72 hours of birth	93 (36)
Male	137 (53)
Exclusively breastfed for 5 – 6.3 months	42 (16)
At least one clinic visit for acute respiratory illness	242 (94)
At least one clinic visit for acute lower respiratory illness	167 (65)
Wasting (weight-for-age z score < -2)	
3 months	70 (27)
12 months	87 (35)
Highest level of formal education completed by mother	
No formal education	92 (36)
Elementary school	92 (36)
Middle school	69 (27)
High school	4 (2)
Own a cell phone	173 (67)
Own a television	160 (62)
Cooking fuel use:	
Only clean burning fuels	107 (42)
Only biomass	16 (6)
Primarily clean fuels but sometimes biomass	134 (52)
Cookstove located inside the home	84 (32)
Usually burn kerosene in the home for any purpose	119 (46)
Tobacco smoked inside the home	72 (28)
	Median (inter-quartile range)
Duration of breastfeeding, in months	30 (23 – 35)
Duration of exclusive breastfeeding, in months	4 (2 – 6)
Number of external windows and doors in the home	2 (1 – 3)
Number of household members	5 (4 – 6)
Living space floor area in square meters	9.6 (7.8 – 11.3)
Number of people per square meter of floor space	1.8 (1.4 – 2.4)
Number of particulate matter measurements per household	12 (11 – 12)
Mean hours per day of PM_2 concentrations >100 $\mu g/m^3$	5.3 (4.0 – 6.9)

Table 2

Number of acute lower respiratory infections (ALRI) observed through two years of age per child enrolled in the Mirpur birth cohort, January 2008 – March 2011 (N=257)

Number of ALRI episodes	N (%)
0	88 (34)
1	64 (25)
2	45 (18)
3	34 (13)
4	11 (4)
5	10 (4)
6	4 (2)
7	1 (0.4)

Table 3

Signs and symptoms associated with acute lower respiratory infection (ALRI) observed in children less than 2 years of age in Mirpur, Dhaka, January 2008 – March 2011 (N=381)

Signs and symptoms	N (%)
Mother reported:	
Cough	380 (99)
Fever	365 (96)
Difficult breathing	247 (65)
Reluctance/inability to feed	99 (25)
Physician observed:	
Tachypnea*	365 (96)
Crepitations	247 (65)
Chest indrawing	158 (42)

*defined by age: >60 breaths per minute for children aged <2 months, ≥50 breaths per minute for children aged 2–11 months, and ≥40 breaths per minute for children aged 12–23 months

Table 4

Incidence rates (IR) (95% confidence interval [CI]) of acute respiratory infections (ARI) and acute lower respiratory infections (ALRI) by age group in the Mirpur birth cohort, January 2008 – March 2011

Age groups (months)		Child years	ARI episodes	IR (95% CI)	ALRI episodes	IR (95% CI)
Overall:	0 – 23	491	969	2.0 (1.9 – 2.1)	381	0.7 (0.7 – 0.8)
	0 – 11	254	495	2.0 (1.8 – 2.1)	231	0.9 (0.8 – 1.0)
	12 – 23	237	475	2.0 (1.8 – 2.2)	151	0.6 (0.5 – 0.7)

Table 5

Incidence rate ratios (95% confidence intervals) using Poisson regression for bivariate associations between incidence of acute lower respiratory infections and risk factors for children under two years of age in the Mirpur birth cohort, January 2008 – March 2011

	Age groups (in months)		
	0 – 23	**0 – 11**	**12 – 23**
Child risk factors			
Weighed <2500 grams within 72 hrs of birth	1.38 (1.12 – 1.69)*	1.39 (1.06 – 1.79)*	1.40 (1.01 – 1.93)*
Wasted at beginning of age interval†	1.28 (1.03 –1.59)*	1.30 (0.99 – 1.71)	1.23 (0.89 – 1.71)
Male	1.23 (1.00 – 1.51)*	1.22 (0.94 – 1.59)	1.24 (0.90 – 1.72)
Exclusively breast fed for 5 – 6.3 months	0.80 (0.60 – 1.07)	0.96 (0.89 – 1.03)	-
Household risk factors			
Per each additional person per square meter of living space	0.99 (0.89 – 1.11)	1.00 (0.87 – 1.16)	0.97 (0.81 – 1.16)
Mother has more than elementary education	0.98 (0.78 – 1.22)	0.83 (0.61 – 1.12)	1.23 (0.88 – 1.72)
Own cell phone and television	0.92 (0.75 – 1.12)	0.92 (0.71– 1.20)	0.92 (0.67 – 1.27)
Member of household smokes cigarettes indoors	1.21 (0.98 – 1.50)	1.28 (0.97 0 1.67)	1.12 (0.80 – 1.58)
Ever use biomass for cooking	1.10 (0.74 – 1.62)	1.18 (0.72 – 1.93)	0.98 (0.52 – 1.87)
Per each hour $PM_{2.5}$ concentrations exceeded 100 μg/m^3	1.04 (0.99 – 1.08)	1.07 (1.01 – 1.13)*	0.98 (0.92 – 1.07)

*p-value ≤0.05

†At 3 months for the 0 – 23 months and 0 – 11 months age groups, and at 12 months for the 12 – 23 months age group.

Table 6

Adjusted incidence rate ratios (95% confidence intervals) using Poisson regression for incidence of acute lower respiratory infections and risk factors for children under two years of age in the Mirpur birth cohort, January 2008 – March 2011

	Age groups (in months)		
	0 – 23	**0 – 11**	**12 – 23**
Weighed <2500 grams within 72 hrs of birth	1.39 (1.07 – 1.82)*	1.46 (1.03 – 2.06)*	1.36 (0.97 – 1.91)
Wasted at beginning of age interval±	0.98 (0.74 – 1.31)	0.94 (0.65 – 1.38)	1.12 (0.79 – 1.59)
Exclusively breastfed for 5 – 6.3 months	0.80 (0.60 – 1.07)	0.95 (0.88 – 1.02)	-
Male sex	1.23 (1.00 – 1.51)*	1.23 (0.95 – 1.61)	1.18 (0.85 – 1.64)
Each additional person per square meter	1.03 (0.92 – 1.16)	1.08 (0.93 – 1.25)	0.99 (0.82 – 1.19)
Mother has more than elementary education	1.03 (0.82 – 1.31)	0.90 (0.66 – 1.23)	1.27 (0.88 – 1.82)
Own both a cell phone and a television	1.00 (0.81 – 1.25)	1.05 (0.79 – 1.38)	0.94 (0.67– 1.32)
Per each hour $PM_{2.5}$ concentrations exceeded 100 μg/m^3	1.04 (0.99 – 1.09)	1.07 (1.01 – 1.14)*	1.00 (0.92 – 1.09)

*p-value ≥0.05

± At 3 months for the 0 – 23 months and 0 – 11 months age groups, and at 12 months for the 12 – 23 months age group